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ASSESSING PATTERNS OF CHANGE IN ANTHROPOMETRIC DIMENSIONS: SECULAR TRENDS OF U.S. ARMY FEMALES 1946-1988

by
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and
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This report presents an analysis of data gathered in 1946, 1977, and 1988 anthropometric surveys of U.S. Army women to assess long-term changes in body dimensions. Fifteen dimensions are analyzed for two racial/cultural groups: Whites and Blacks. The results of these analyses describe trends that are slow, erratic, and yet statistically significant as linear models. Several hypotheses, drawn from conventional explanations of secular trends, are tested against the anthropometric trends observed in Army women. The application of these hypotheses, however, was deemed to be either inappropriate for these data or unsatisfactory in the ability to explain the observed phenomenon. It is concluded that shifting cultural forces that influence which women join the Army are the most likely cause of the observed patterns. Because these cultural actions have undergone so much change in the last half of the 20th century, it is impossible to establish a basis for predicting the anthropometric dimensions of future populations. Therefore, it is recommended that race-specific data from the most recent anthropometric survey of Army women (1988) be utilized with appropriate race-specific weights to predict Army women's body dimension values in the near future.

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ANTHROPOMETRY, SIZES(DIMENSIONS), HUMAN BODY SIZE, ARMY PERSONNEL, RACE(ANTHROPOLOGY), FEMALE SOLDIERS, FEMALES, MODELS, DEMOGRAPHY, SECULAR TRENDS, DATA ANALYSIS

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PREFACE

Often military materiel systems are utilized for several decades and in the case of transportation systems such as aircraft they may take several decades to design, test, and field. In such cases it is helpful to be able to anticipate the anthropometric distributions of future military populations. The purpose of this study was to quantify secular trends in U.S. Army women so that they could be used, when appropriate, in estimating anthropometric distributions of future Army women. This work was funded under program 728012.12, "Currency of the Anthropometric Data Base", during fiscal years FY91 and FY92.

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Assessing Patterns of Change in Anthropometric Dimensions: Secular Trends of U.S. Army Females 1946-1988

1. INTRODUCTION

The mean values of a population's anthropometric dimensions change over time, a phenomenon known as secular trend (Bock and Sykes, 1989; Damon, 1968; Ohyama et al., 1987; Polednak, 1975; Takahashi, 1986). By anticipating these trends in the US Army population and considering them in clothing and equipment design, it is possible to extend the useful lifetime of an item through awareness of dimensional changes in the user population.

Although precise causes are difficult to determine, many factors may contribute to changes in the body dimensions of a population. Some of the more commonly suggested conditions that might result in secular trends are: changes in health, changes in nutrition, changes in the rates of growth and maturation, changes in population mixtures due to immigration, changes in socioeconomic status, and changes in cultural attitudes about physical fitness and idealized body shape (Schreider, 1967; Meredith, 1976; Frisancho et al., 1977; Bielicki et al., 1981; Flegal et al., 1988a; 1988b; Lasker and Mascie-Taylor, 1989). These sources of change are not mutually exclusive, rather there is much interaction between them. This makes it difficult to pinpoint precise sources of any particular secular trend or to foresee the result of changes in one or more of these conditions.

A recent study of the secular trends of US Army men (Greiner and Cordon, 1990) shows that many of their secular trends are consistent with changing cultural attitudes regarding health and physical fitness. Different population subgroups, however, may be influenced by cultural attitudes at different levels. Thus, different rates of secular trend are observed for White, Black, Hispanic and Asian/Pacific Islander men. One group, Asian/Pacific Islander men, is so different that its secular trends are explained best by immigration patterns rather than by cultural attitudes of physical fitness. Thus, the primary explanation of secular trends for one group may not be appropriate for another group.

Discussions of secular trend usually focus on biological groups, the reproductive units of a population. The Army, however, does not comprise a population in the biological sense. Instead, the Army builds its population through a nonrandom sampling of the US population. Many cultural attributes influence the nature of that sampling, such as: conscription, volunteerism, and prevailing attitudes about joining the Army. Each racial/cultural group might also face different cultural attitudes about

military service. These differences among cultural groups may have a greater influence in forming secular trend patterns within the all volunteer force than they did during periods in which recruits were drafted for service.

The Army is a heterogeneous population. Greiner and Gordon (1990) show that changes in the demographic make up of the Army have a greater influence on the population's mean anthropometric values than do the individual patterns of secular trend within each racial/cultural group. Therefore, secular trends of the Army population are best expressed as the sum of tne patterns of its constituent groups. In many ways, women in the Army are culturally and biologically distinct from Army men. Thus, the secular trend patterns of Army men cannot necessarily be used to model the secular trends of Army women. Instead, secular trend models should view Army women as a distinct population, one with its own constituent racial/cultural subgroups.

Women represent an increasing proportion of the Army population. Therefore, it is becoming increasingly important to produce equipment designs that accommodate female body dimensions. Data are now available from several anthropometric surveys of women in the Army (Randall and Munro, 1949; Laubach et al., 1977b; Gordon et al., 1989). This report makes use of those data in its descriptions of secular trend patterns. The aims of this analysis are to: 1) quantitatively describe the secular trends of different body dimensions; 2) contrast the rates of change among different racial/cultural groups; 3) identify the group that is undergoing the greatest rate of change; and 4) provide guidance for the use of these trends in forming statements of the anthropometric values of future populations of women in the Army.

The discussion that follows focuses on several substantive differences between the 1946, 1977, and 1988 data sets, and why those differences may be responsible for the limited success in achieving the stated research objectives.

2. HISTORY OF WOMEN IN THE ARMY

In the broadest sense, women comprise a distinct cultural group within the Army population. Many of the patterns of change associated with Army women may be attributed to this distinction. As women's reasons for enlisting changed (or the Army's reasons for recruiting women changed), the pool of women available for military service varied also. Thus, cultural attitudes of women, and about women, have had a strong influence on how the Army drew women from the general population. Although few important changes have been made in the anthropometric restrictions for women in the Army, culturally determined changes in the sampling pool may be subtly related to other agents that influence anthropometric distributions. This form of sampling bias could have had a strong influence in shaping the anthropometric distributions of the Army women population. Therefore, a brief review of the women's recent

participation in the Army provides a starting point in the analysis of their patterns of secular trend.

The 20th century saw a slow process of formalizing and expanding the role of women in the Army (see Table 1). Military experience during the Spanish-American War and the cultural association of nursing as women's work led to the first formalized positions for women in the military. In 1901 Congress authorized the establishment of the Army Nurse Corps (ANC). Although this was a military organization, members of the ANC did not hold Army rank, were not paid on the military scale, and did not receive veteran's benefits.

World War I saw the first mobilization of the American population in the 20th century. The American military expedition in Europe was largely aided in its clerical and administrative activities by members of the British Women's Auxiliary Army Corps. The example of these women and the need for more soldiers resulted in the proposed formation of a Women's Service Corps within the American Army. A change in draft age increased the number of men available for military service and thus decreased the immediate need for participation by women. It was, however, the conclusion of the war in November 1918 that finally halted serious consideration of enlisting women into the Army.

The Women's Service Corps proposal was debated in the following decades, but no firm action was ever taken. World War II was the next national emergency that saw a shortage of "manpower" that could be filled by women. In 1941 Congress passed a bill that called for the organization of the Women's Army Auxiliary Corps (WAAC). Based on the British model,

> ***The WAAC was to be a corps of 25,000 women for noncombatant service; it was "not part of the Army but it shall be the only women's organization authorized to serve with the Army, exclusive of the Army Nurse Corps" [Treadwell, 1954:19].***

The mission of the WAAC was deliberately defined to make use of skilled women from the civilian workforce, rather than the utilization of women as unskilled laborers. Thus, these women were intended to fill clerical and administrative positions and thereby allow more men to be combat soldiers (Treadwell, 1954; Morden, 1990).

Because the WAAC existed apart from the Army it, in effect, constituted its own branch of the military, with separate ranks, pay grades, and enlistment requirements. At that time, the cultural concept of women in the military carried with it the stigma of "camp followers". From the start, attempts were made to counter this image by requiring WAACs to be women of "high moral standards" (Treadwell, 1954); any perceived breach of moral conduct was grounds for immediate discharge. These conditions resulted in military women constituting a biased sample of American women to a much greater extent than their male counterparts. To be a WAAC a woman had to

TABLE 1.
Important Milestones for Women in the Army
(Adapted from Stiehm, 1989)

1901	Establishment of the Army Nurse Corps, a military organization without Army rank, equal pay or benefits
1918	Proposal debated to organize a "Women's Service Corps" to fill clerical positions; change in draft age allowed the use of men instead
1942	Establishment of the Women's Army Auxiliary Corps (WAAC), separate from the Army Nurse Corps.
1943	WAAC admitted to full Army status as the Women's Army Corps (WAC)
1944	Full military rank, pay, and benefits granted to Army Nurse Corps
1948	Women's Armed Services Integration Act; Women limited to 2% of total military strength
1955	Army Nurse and Medical Specialists Corps opened to men
1967	P.L. 90-130 removes some restrictions of careers of military women as well as the 2% limitation on women's participation
1971	Women allowed to participate in college ROTC
1972	End of military draft, beginning of the All Volunteer Force
1973	Women given dependency benefits
1974	PL 93-290 voids age differential for enlistment
1975	DOD ends involuntary discharge for pregnancy
1976	Women enter military academies
1977	Army approves integrating men and women during Basic Training
1978	Women's Army Corps abolished
1980	Draft registration for men reinstated
1982	Resegregation of men and women during Basic Training

be already trained in the required skills, she had to be of unquestioned moral background, and she had to have personal character that could withstand the slanders associated with military service for a woman.

The success of the WAACs led, in 1943, to serious discussions about the possibilities of drafting women, ages 20 through 44, into military service. Limitations of the auxiliary system made this impractical. As a response to those limitations, however, the WAAC was admitted to full Army status as the Women's Army Corps (WAC). This change did not alter the role of women in any way, but rather recognized the WAC as an important part of the Army. Women's participation was no longer an aspect of war expediency. Thereafter, women had a permanent role in the American Army.

After World War II women's roles in the military were further formalized by granting full rank, pay and benefits to the members of the ANC and WAC. The Women's Armed Services Integration Act of 1948 provided the final legal foundation for women's participation in the military. This law, however, still maintained restrictions that would make it difficult for a woman to choose to follow, or advance in, a military career. Women now held regular military rank but could not, as officers, advance beyond the rank of lieutenant colonel. The rank of colonel was reserved for the corps commander, who held that post for four years and then reverted to the rank of lieutenant colonel (Binkin and Bach, 1977; Stiehm, 1989). Women under age 18 were refused enlistment, and those under age 21 required parental permission. Women could not receive dependency benefits for their husbands and children unless the woman was the family's sole means of support. Pregnancy was grounds for immediate discharge, and marriage was viewed as a reason for voluntary separation. Further, the act restricted women from participation in combat roles, barring them from combat ships and aircraft by law and from "performing services as may be prescribed by the Secretary of the Army" (Stiehm, 1989:109). Finally, this act also stipulated that women would never constitute greater than 2% of the military's total strength.

During this period the primary purpose of the WAC was to maintain a trained nucleus of women that would be available for service in times of national emergency (Binkin and Bach, 1977; Goldich, 1980). Women in American society, however, showed no great desire to join the Army or any military service. During the Korean conflict an attempt was made to recruit 100,000 women to meet personnel demands. General lack of public enthusiasm and the absence of the perception of national war emergency resulted in the failure of this recruiting effort (Binkin and Bach, 1977). Perceptions of women's roles, and their relationship to military service, apparently had not changed. Women's military participation varied from 1.0% to 1.5% (averaging 1.2%) between 1948 and 1970, but never came close to the 2% legal limit (Binkin and Bach, 1977).

More rapid changes affecting the status of women in the Army occurred during the 1960's and 1970's. In 1967 Congress passed public law 90-130. This law lifted

the 2% barrier, as well as the rank restrictions. More important, women could participate in almost all military specialties; combat restrictions being the only remaining impediment. In 1971 career opportunities were further enhanced by allowing women to participate in ROTC programs. In rapid succession women were granted dependency benefits in 1973, the age differential for enlistment ended in 1974, involuntary discharge for pregnancy was halted in 1975, and women began to be admitted into the military academies in 1976. It is difficult to know whether these changes were the result or the cause of changing perceptions of and about women and the military. Yet, the important change brought about during these years was that more women began to view the military as a potential career choice. Up to the middle 1970's the numbers of women in the Army never approached the legal 2% limit (Binkin and Bach, 1977). These changes, however, saw a steady increase in women's military participation until today they number over 11% of the Army.

In the early 1970's American attitudes turned against military service. Throughout this decade the All Volunteer Force (AVF) was viewed as an impending failure that was seriously undermining American military strength (Goldich, 1980). One response to the decline in the number of available male recruits was an increase in female recruits. This lead to the gradual integration of women into the mainstream of military functions, which culminated in the end of the Women's Army Corps in 1977. Despite the end to most occupational restrictions, up to this time Army women had still filled mostly medical and clerical positions. Women did not go through the rigorous basic combat training of the male soldier. With the end of the WAC this exclusion changed, and it was not seen as a welcome change by all women (Rogan, 1981; Morden, 1990). The end of the WAC resulted in a minor turnover in the population of Army women.

Some women responded by leaving the service, while others looked on integration as a chance to seize greater opportunities (Stiehm, 1989). The military, however, continued to look to women to make up for shortages of acceptable recruits (Office of the Assistant Secretary of Defense, 1987). The greater, and now integrated, role of women generated greater controversy within American society about women in the military, especially women in combat (Goldich, 1980; Goldman and Wiegand, 1982; Moskos, 1982). The perceived failings of the AVF contributed to the reinstatement of draft registration for men in 1980. Although President Carter also proposed the registration of women, Congress deemed such actions inappropriate. This congressional action, and the now-apparent success of the AVF, halted the rapid changes of women's roles in the Army during the 1980's (Stiehm, 1989).

In the 1990's current events have once again raised the question of the role of women in the Army and the armed forces. Changes in military weaponry and tactics are beginning to suggest that there may be no "noncombat" area in a field of operations, thus making legislated combat exclusions meaningless. Combat exclusions in the Army are based upon policy rather than law, and therefore can change at any time. Depending upon how the combat issue is resolved, more women may consider

an Army career (by taking positions opened by women who exercise the combat option) or more women may leave the Army (to avoid unwanted combat experience). It is impossible to presage the exact population response to a modification of combat exclusion policies. Much depends on the nature of that modification and on the prevalent social attitudes. Debates on this issue no longer center on whether women can be capable combat soldiers, but whether the American public could accept women as combat casualties (Moskos, 1982; Eckman, 1989; Ralston, 1991). Thus, the attitudes of American society may eventually decide this issue. Congress has debated proposals that could repeal, or radically redefine, the laws that exclude women from combat positions (Gellman, 1991; Ralston, 1991). And although a presidential commission recommended that women be allowed on warships but excluded from air and ground combat roles (Abrams, 1992), full participation in combat scenarios can be looked upon as the next major milestone that might effect a change in the population of Army women.

In sum, the recent experience of women in the Army is characterized by broadened career opportunities and increased acceptance of military women by American society. Opportunities, because the role defined for women has changed. Acceptance, because steadily increasing numbers of women consider, and are recruited for, military service. This transition need not be associated with overt anthropometric values for it to influence the Army population. This review has shown that outside of nursing the role of women in the Army has evolved from "secretary" to "soldier," a trend that appears to be continuing. One need only consult one's own stereotypical images of women in these two professions to realize that anthropometric differences may accompany this trend. Women that conform to the image of the soldier are more likely to be channeled into the selection pool of Army applicants (Flegal et al., 1988a; 1988b; Lasker and Mascie-Taylor, 1989; Floud et al., 1990). As women's roles within the Army were redefined, and American culture reshaped its images of women filling those roles, the Army's sampling of the U.S. population, and thus the Army's population, changed. The current analysis of secular trends for Army women can thus be expected to reflect the influence of these changing attitudes.

3. METHODS

Data available for this analysis come from the 1946, 1977, and 1988 anthropometric surveys of US Army women. An underlying aim of this project was to replicate, as closely as possible, the analysis of secular trends of US Army males (Greiner and Gordon, 1990). Some of the data collection methods used in the female surveys, however, prevent a close parallel analysis. For example, although the 1988 survey gathered detailed data on race and ethnicity, the earlier surveys only identified persons as White, Black or Asian. The separate analysis of four racial/cultural groups, as was done with the male data, therefore was not possible. Instead, the available group designations were used to sort the data into three racial/cultural groups

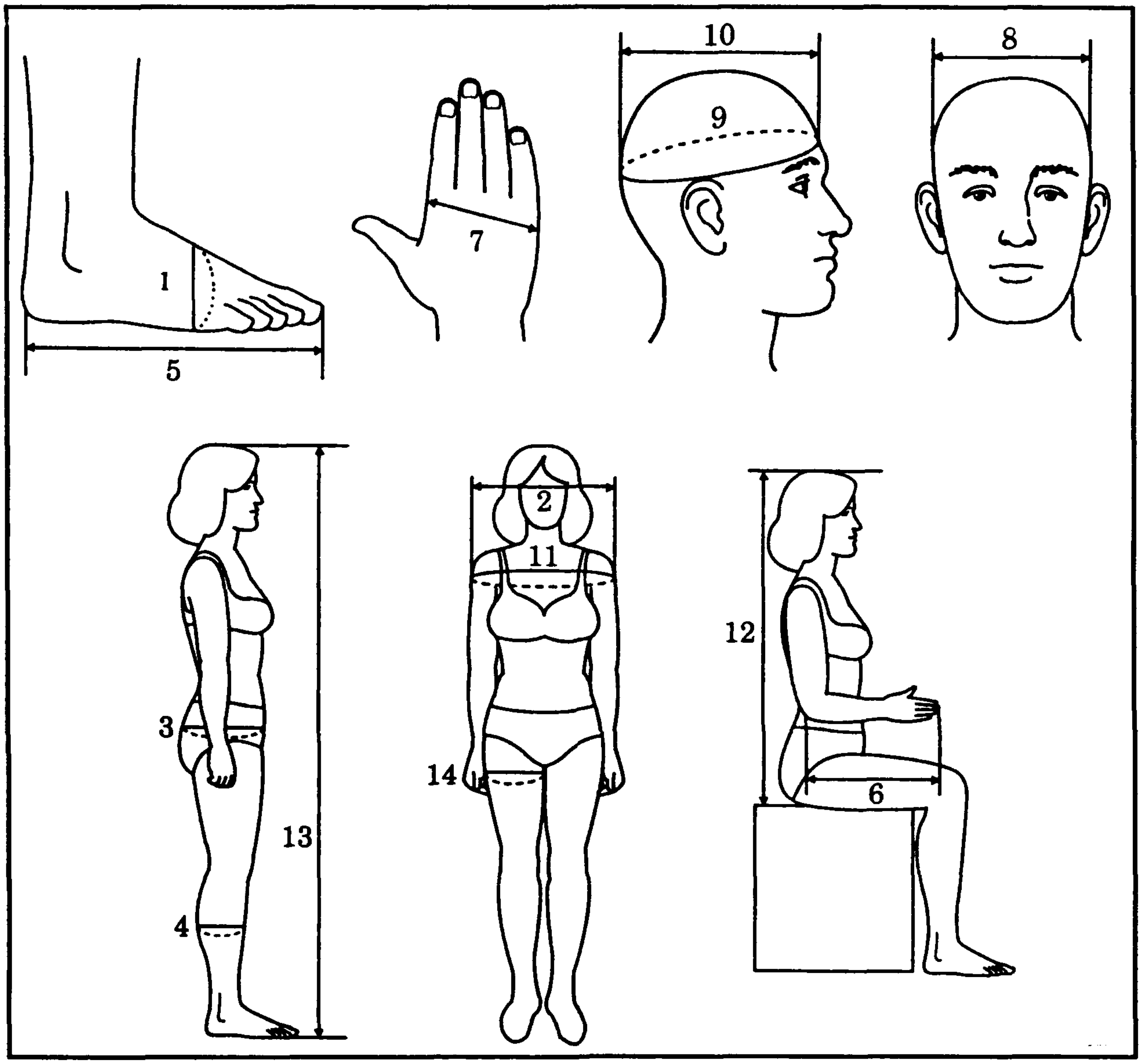

Figure 1. Visual guide to the anthropometric dimensions.

1. Ball of Foot Circumference
2. Bideltoid Breadth
3. Buttock Circumference
4. Calf Circumference
5. Foot Length
6. Forearm-Hand Length
7. Hand Breadth
8. Head Breadth
9. Head Circumference
10. Head Length
11. Shoulder Circumference
12. Sitting Height
13. Stature
14. Thigh Circumference
15. Weight

(Hispanics in the 1988 survey were recoded as White or Black using ethnicity data). Similarly, a comparison of the measuring techniques used in the different surveys (Randall and Baer, 1951; Laubach, et al., 1977a; Clauser, et al., 1988) identified only 15 comparable dimensions that could be investigated for secular trends (see Figure 1). This represents a smaller number of dimensions than was analyzed for the males, and only 10 of these dimensions overlap with the analysis of Army men.

Long-term trends were quantified using least-squares regression analysis, following methods established in the analysis of male trends (Greiner and Gordon, 1990)[1] . Individuals were grouped into cohorts that represent five-year birth intervals (see Tables 2 and 3). This procedure divided the data into 17 birthyear cohorts.

TABLE 2.
Cohort Breakdown for the Three Surveys

Cohort	Birthyears	Subjects' Ages When Measured		
		1946 Survey	1977 Survey	1988 Survey
1	1885-1889	57-		
2	1890-1894	52-56		
3	1895-1899	47-51		
4	1900-1904	42-46		
5	1905-1909	37-41		
6	1910-1914	32-36		
7	1915-1919	27-31	58-	
8	1920-1924	22-26	53-57	
9	1925-1929	-21	48-52	59-
10	1930-1934		43-47	54-58
11	1935-1939		38-42	49-53
12	1940-1944		33-37	44-48
13	1945-1949		28-32	39-43
14	1950-1954		23-27	34-38
15	1955-1959		18-22	29-33
16	1960-1964		-17	24-28
17	1965-1969			19-23
18	1970-1974			-18

1 Application of the statistical methods used on males resulted in some unusual trend patterns in this study. An alternative estimation method (described in Appendix A) was also tried. The alternative method generated similar results, leading us to conclude that the unusual trend patterns are not artifacts of the trend estimation methods used.

TABLE 3
Cohort Breakdown by Racial/Cultural Group for the Three Surveys

1946 Survey		Whites		Blacks		Asians	
Cohort	Birthyears	N	Mean Age	N	Mean Age	N	Mean Age
2	1890-1894	1	52.0	0		0	
3	1895-1899	55	48.3	0		0	
4	1900-1904	193	43.8	3	45.0	1	42.0
5	1905-1909	360	38.7	10	38.8	0	
6	1910-1914	732	33.7	17	33.1	2	33.5
7	1915-1919	1529	28.7	61	28.7	4	28.3
8	1920-1924	4514	23.7	173	23.7	6	24.2
9	1925-1929	415	20.9	15	20.9	0	

1977 Survey		Whites		Blacks		Asians	
Cohort	Birthyears	N	Mean Age	N	Mean Age	N	Mean Age
9	1925-1929	3	50.0	1	49.0	0	
10	1930-1934	13	45.3	2	45.0	0	
11	1935-1939	9	39.6	3	40.0	0	
12	1940-1944	31	34.7	11	34.6	1	33.0
13	1945-1949	74	29.5	34	29.5	4	29.0
14	1950-1954	308	24.6	68	24.8	9	24.1
15	1955-1959	517	19.7	176	19.8	11	20.2
16	1960-1964	15	17.0	3	17.0	0	

1988 Survey		Whites		Blacks		Asians	
Cohort	Birthyears	N	Mean Age	N	Mean Age	N	Mean Age
11	1935-1939	2	49.5	0		0	
12	1940-1944	12	45.7	11	45.5	3	45.7
13	1945-1949	44	40.5	31	40.1	3	40.3
14	1950-1954	153	35.6	129	35.5	18	35.9
15	1955-1959	232	31.0	275	31.0	25	31.2
16	1960-1964	393	25.7	391	25.9	47	25.9
17	1965-1969	563	20.8	532	20.8	40	20.7
18	1970-1974	40	18.0	40	18.0	2	18.0

The mean value for each body dimension was then calculated for each cohort, and these were submitted to regression analysis. To accommodate very large differences in sample sizes for each cohort, each cohort's mean value was weighted by cohort size in the statistical analyses. However, before attempting to present interpretations of the observed data patterns, it is important to state some of the assumptions and data limitations associated with this type of analysis.

Least-squares modeling minimizes the sum of the squared residuals to determine the best fitting line. Generally, this means that an outlier can have an undue influence in the resulting regression line. In this study, most of the extreme outliers represent cohorts with very small sample sizes. Thus, weighting cohorts by sample size minimizes the influence of the outlying cohorts. Weighting cohorts by sample size also means that surveys with the largest total sample will have the greatest influence on the resulting regression line.

In this study, survey population sizes differ dramatically:

	Whites	Blacks	Asians
1946	7799	279	13
1977	970	298	25
1988	1439	1409	138

These differences mean that cohorts associated with the 1988 population would have the greatest influence in forming regression models for Blacks and Asians. However, cohorts from 1946 would have the greatest influence in forming regression models for Whites. If these survey samples had been drawn from roughly the same populations, these differences in sample size might not be of concern. However, the history of Army women shows that there have been important differences as to why women have been attracted to Army service, which could change the nature of the population described by each of the surveys. For this reason, an unweighted least squares analysis was also undertaken. It produced slightly different regression lines, but the results were equally erratic and thus they are not reported here.

Another potential limitation exists in the small sample sizes associated with Asians; only in the 1988 survey data does the sample size approach reasonable levels. The sparsity of Asian data increases the likelihood that the resulting trend models would be merely statistical artifacts. In the 1988 survey, two cohorts, 16 and 17, contain over half of the Asian sample. Because these are adjacent cohorts, they provide no real time depth to the secular trend model. Therefore, all observed trends for the Asian racial/cultural group would have to be treated with great skepticism. For this reason, Asians were dropped from further consideration in this analysis.

Although three major surveys of Army women are available to build secular trend models, when these data are plotted against birthyear cohort there is a consistent

separation of the 1946 data set even after adjustments for subjects' ages at the time they were measured (most dramatically seen in a scatterplot of Head Breadth vs. Birthyear Cohort, see Figure 2). The special nature of the 1946 data set may explain this separation. First, the bulk of these women experienced their growth years during the great depression of the 1930's. Inasmuch as economic environment influences growth, these women might be expected to show unusual anthropometric values when compared with other cohorts (Bock and Sykes, 1989). Second, the women in the 1946 data set represent the formation of the Women's Army Corps in response to the national emergency of WWII. As an event, WWII represents a complex, unique and discontinuous process whose direct and indirect influences on anthropometric values are difficult to discern. There are insufficient data to "correct" for the unique influences that WWII sampling may have had on Army women's anthropometric distributions. Therefore, the only alternative is to acknowledge that the 1946 survey data represent a separate target population that cannot be linked to the later surveys in a larger trend model. Therefore, the 1946 data were excluded from further consideration in this analysis.

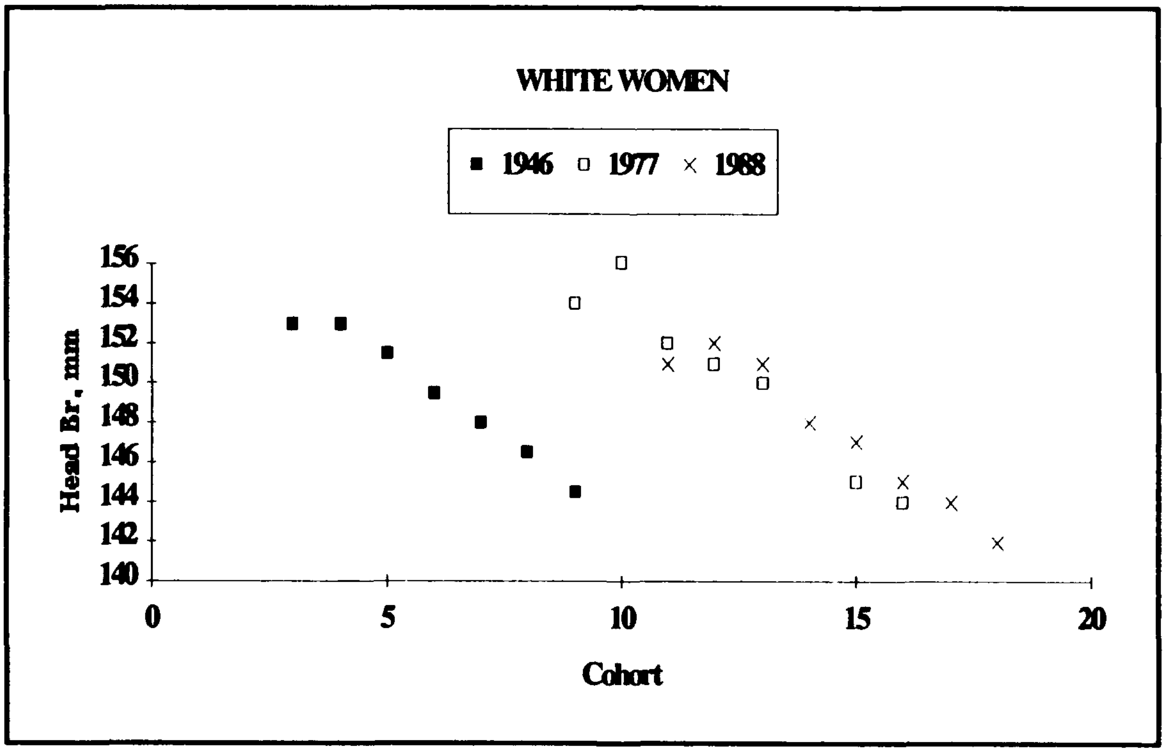

Figure 2. Scatterplot of age-adjusted head breadth (mm) vs. birthyear cohort for White women

The data remaining for this analysis are composed of the White and Black women measured in the 1977 and 1988 anthropometric surveys. However, because these women are grouped into cohorts by birthyear, the cohort values between the data sets vary according to both birthyear and age at the time of measurement. Therefore, the effects of age-related change need to be controlled. Because a cohort is made up of persons born in a specific interval of five years, the observed difference in values between a cohort in 1977 and the same cohort in 1988 can be used to estimate the influence of age differences at the time of measurement. This difference can be read as the change due to age in an 11-year period. Multiplying this value by 5/11 converts it into the rate of age-related change per five-year cohort. This method was repeated so that separate rates of age-related change were calculated for each dimension for each birthyear that overlaps the two surveys.

This method of examining age-related change creates a series of two-point linear models. The inherent weakness of a two-point linear model was addressed by using the mean value of the slopes of these models, for each dimension, as the best estimate of the rate of age-related change (Hyde, 1980). This process was repeated for the two racial/cultural groups. Table 4 presents the age correction factors for each dimension that resulted from this process.

TABLE 4.
Age Correction Factors for Women

Dimension	Age Factors	
	Whites	Blacks
1. Ball of Foot Circumference	-4.20	-8.13
2. Bideltoid Breadth	3.20	0.29
3. Buttock Circumference	2.01	5.39
4. Calf Circumference	0.06	0.35
5. Foot Length	0.75	-0.83
6. Forearm-Hand Length	0.96	0.80
7. Hand Breadth	0.37	0.02
8. Head Breadth	-1.18	-1.21
9. Head Circumference	-1.27	-4.56
10. Head Length	0.25	-0.68
11. Shoulder Circumference	4.36	-1.81
12. Sitting Height	3.11	3.31
13. Stature	0.87	-0.61
14. Thigh Circumference	1.67	-0.66
15. Weight	0.56	-0.46

Mean rates of age-related change were used to control for the effects of age within each cohort. Following the example of Greiner and Gordon (1990), the age of 20 was used as the age of standard expression for anthropometric dimensions. Age effects were controlled by adjusting cohort values according to the mean age at time of measurement for persons within that cohort, as follows:

$$\mathbf{AAV = V - AF\ (((Y - 1900)/5) - C)}$$

In this equation **AAV** is the Age Adjusted Value; **V** is the observed anthropometric Value; **AF** is the Age correction Factor; **Y** is the survey Year rounded down to 5-year intervals; and **C** is the birthyear Cohort. The term **(Y**-1900)/5 is the age cohort that would include 20-year olds for the year **Y**.

Secular trends were studied by regressing the age-adjusted dimensions with cohort. These bivariate regressions produce the following generic equation:

$$\mathbf{AAV = a\,C + b}$$

In this linear equation **b** is the y-intercept constant and **a** is the slope of the line. Because this equation describes the relationship between cohort (time) and an anthropometric dimension, controlled for age, the term **a** is the rate of secular change. The statistical significance of secular trend rates for each racial/cultural group was evaluated for each dimension using *F* tests, corrected for 15 comparisons (Sokal and Rohlf, 1981).

Wherever feasible, analyses of the revealed secular trend patterns were based on the same procedures employed by Greiner and Gordon (1990) in the analysis of US Army men. Comparisons of secular trend rates between racial/cultural groups were made using SPSS analysis of covariance software. Slope comparisons with low *F* values and significance levels greater than 0.05 corrected for multiple comparisons were not considered to be statistically different. Finally, immigration patterns were evaluated for each group using a Mantel-Haenszel Chi-Square test of the linear relationships between birthplace (USA vs. Non-USA) and birthyear. Adjacent cohorts were sometimes pooled to avoid sparse cells that would compromise statistical assumptions. Cells were then scored according to the median birthyear of their membership. Significant results indicated an increasing trend in foreign born membership of a specific racial/cultural group, and thus indicated that migration could be having an influence on perceived trend patterns.

4. RESULTS

Appendix B contains tables listing means by race and cohort for each body dimension; Appendix C presents these data, after age-adjustment, in race-specific

scatterplots for each dimension. Table 5 presents the rates of secular change calculated in this study. Tables 6 and 7 provide full statistical descriptions of the secular trend regression models. Each dimension was also explored using nonlinear regression techniques. In no instance, however, were models markedly improved as judged by standard errors and coefficients of determination. Therefore, linear models were retained for all dimensions. All trend rates in Table 5 are significantly different from zero at the .05 level or better after a Bonferroni correction for 15 tests. White and Black rates are significantly different from each other for al' dimensions at the .05 level or better after Bonferroni correction. Data on allowable observer error is also presented in Table 5 to provide a means of assessing the biological relevance of trend rates. Trend rates less than the observer error value could not be reliably detected after a five-year period. Most of the reported trend values are substantially lower than their allowable observer error.

TABLE 5.
Secular Trend Rates for Whites and Blacks[2]

Dimension	Whites	Blacks	Obs Error
Ball of Foot Circumference	-4.86	-9.22	4.00
Bideltoid Breadth	2.94	-1.84	8.00
Buttock Circumference	-4.18	-6.16	12.00
Calf Circumference	-0.28	-0.67	5.00
Foot Length	-0.85	-0.92	3.00
Forearm-Hand Length	0.75	0.64	4.00
Hand Breadth	0.27	-0.34	2.00
Head Breadth	-1.43	-1.56	2.00
Head Circumference	-1.93	-5.71	5.00
Head Length	0.18	-0.96	2.00
Shoulder Circumference	3.87	-7.65	22.00
Sitting Height	2.04	2.45	6.00
Stature	-1.31	-0.59	10.00
Thigh Circumference	-1.17	-5.77	6.00
Weight	-0.08	-1.52	0.30

[2] Secular trend units are mm per cohort (a 5-year period), except weight which is in kg/cohort. Allowable observer error units are mm and kg; values are taken from Gordon and coworkers (1989).

TABLE 6.
Secular Trend Models for Whites[3]

Dimension	Slope	Intercept	*SEE*	r^2
Ball of Foot Circumference	-4.86	305	1.13	.97
Bideltoid Breadth	2.94	379	3.57	.57
Buttock Circumference	-4.18	1026	11.44	.21
Calf Circumference	-0.28	357	2.09	.03
Foot Length	-0.85	255	1.17	.51
Forearm-Hand Length	0.75	420	1.70	.28
Hand Breadth	0.27	74	0.42	.45
Head Breadth	-1.43	168	0.74	.88
Head Circumference	-1.93	576	1.04	.87
Head Length	0.18	184	0.47	.23
Shoulder Circumference	3.87	951	9.12	.26
Sitting Height	2.04	829	2.87	.50
Stature	-1.31	1652	5.43	.10
Thigh Circumference	-1.17	589	6.53	.06
Weight	-0.08	61	1.45	.01

TABLE 7.
Secular Trend Models for Blacks[3]

Dimension	Slope	Intercept	*SEE*	r^2
Ball of Foot Circumference	-9.22	380	1.20	.99
Bideltoid Breadth	-1.84	460	6.02	.14
Buttock Circumference	-6.16	1054	10.82	.35
Calf Circumference	-0.67	361	2.46	.11
Foot Length	-0.92	265	0.78	.70
Forearm-Hand Length	0.64	445	1.72	.19
Hand Breadth	-0.34	85	0.55	.39
Head Breadth	-1.56	170	0.67	.90
Head Circumference	-5.71	645	1.84	.94
Head Length	-0.96	204	0.59	.82
Shoulder Circumference	-7.65	1150	14.18	.33
Sitting Height	2.45	793	2.91	.54
Stature	-0.59	1640	4.31	.03
Thigh Circumference	-5.77	675	10.34	.35
Weight	-1.52	86	2.14	.46

[3] All slopes are significantly different from zero at the .05 level or better after Bonferroni correction for 15 tests.

Immigration patterns were evaluated using a Mantel-Haenszel chi-square test (Mantel, 1963) of the linear relationship between birthyear and birthplace (USA vs. non-USA). Table 8 shows the results of that evaluation. The division of data by birthplace shows that both Whites and Blacks are predominantly American born. These tests show that no significant trend in the immigration patterns of either of the racial/cultural groups has occurred. Therefore, it is unlikely that the observed patterns of secular change are greatly influenced by migration.

TABLE 8.
Evaluation of Immigration Patterns: Whites and Blacks

WHITES: OBSERVED/EXPECTED VALUES					
Birthplace	Median Birthyear				
	1946	1953	1957	1963	1968
USA	176.0 180.1	450.0 441.6	708.0 715.6	391.0 390.9	579.0 575.8
Non-USA	12.0 7.9	11.0 19.4	39.0 31.4	17.0 17.1	22.0 25.2
Mantel-Haenszel Chi-Square = 0.54083, *df*=1, *p*=.4621					

BLACKS: OBSERVED/EXPECTED VALUES				
Birthplace	Median Birthyear			
	1951	1957	1962	1968
USA	277.0 278.1	429.0 431.2	383.0 379.2	550.0 550.5
Non-USA	12.0 10.9	19.0 16.8	11.0 14.8	22.0 21.5
Mantel-Haenszel Chi-Square = 0.17717, *df*=1, *p*=.6738				

5. DISCUSSION

For almost all dimensions, the secular trends of women in the Army can best be described as weak. Although all trends are significantly different from zero, few dimensions approach the level of their allowable observer error. This means that a great deal of time must pass before the observed trends could be reliably detected using current anthropometric techniques. Similarly, coefficients of determination (r^2) are low for most of the dimensions; almost two-thirds of the evaluated dimensions have r^2 values less than 0.5. This means that less than one half of their variance among cohort

values can be associated with the progression of time. Using the patterns of secular trends of Army men (Greiner and Gordon, 1990) as a basis for comparison, Army women might be expected to show a pattern of slow but steady change. However, the results of this analysis suggest that the general pattern of secular trend for Army women is one of no appreciable change. Therefore, the aim of this discussion is to explore the reasons for the different secular trend patterns between Army men and women.

Much scientific inquiry centers on whether secular trends have slowed or stopped in Western societies (Bakwin and McLaughlin, 1964; Damon, 1968; Flegal et al., 1988a; 1988b; Bock and Sykes, 1989). Conventional studies attribute secular changes in body dimensions to one or more of several factors: 1) changes in measuring technique, 2) population changes through migration, 3) changes in the cultural ideals of body shape, and 4) changes in economic status which influence health and nutrition (Meredith, 1976; Frisancho et al., 1977; Bielicki et al., 1981; Takahashi, 1986; Flegal et al., 1988a; 1988b; Greiner and Gordon, 1990). The biocultural interactions of these conditions have resulted in researchers using secular trends as indicators of sociocultural processes as often as researchers claim them to be the by-products of sociocultural change (Relethford and Lees, 1981; McCullough, 1982; Price, et al., 1987; Lasker and Mascie-Taylor, 1989). Thus, the direction, or absence, of a secular trend is closely associated with the biocultural processes that influence a population. These influencing conditions, however, refer to processes that affect biological populations. The Army is not a population in the biological sense. Instead, the Army comprises a nonrandom sampling of the US population. Therefore, a secular trend pattern in the Army population might also result from a change in the way soldiers are drawn from the US population. Thus, change in accession strategy can be seen as a fifth condition that may result in anthropometric change in the Army population.

Each of these five sources of change will be examined in turn as candidates for the best explanation of the observed secular trend patterns. Although each condition will be examined as a sole influence, it should be recognized that all these forces are, and have been, influencing the Army population. The purpose of this discussion is to identify the condition that might have preeminence in explaining the secular trend patterns for women in the Army.

Changes in measuring techniques (condition 1) might produce a pattern of change that would appear as a shift in anthropometric values between survey populations. The measured values of some dimensions can vary according to the subject's posture, the subject's stage in the breathing cycle, or through the improper identification of appropriate landmarks. These technique differences would then be incorrectly interpreted as a secular trend between populations. However, the selection of dimensions used in this study was based on a careful comparison of the descriptions of measuring techniques, so that this phenomenon should be minimal. In addition, technique differences would also contribute to differences between identical birthyear cohorts that were measured in different surveys. So a directional change due to

differences in measuring technique would be included, albeit incorrectly, in estimates of age-related change. The age adjustment process would thus correct for any undetected differences in measuring techniques, and ensure that differences in measuring techniques would be unlikely to contribute to the patterns of secular trend described in this study.

Still, because the scatterplots of several dimensions describe roughly parallel lines between the two survey populations (see Appendix C), these patterns might be ascribed to subtle differences in measuring technique. Despite the careful comparison of measurement descriptions used in the selection of dimensions for this analysis, it could be possible that subtle differences might exist that defy correction in the age adjustment process. The influence of these subtle measuring technique differences would have been dependent upon the training of the measuring personnel. Therefore, these differences might not be apparent in a comparison of measurement descriptions. However, the pattern of parallel trends also appears in the scatterplots of weight (see Figure C-15).

Weight is a dimension that is not greatly dependent upon measurer skill or subject posture. Clauser, et al. (1986) state that the precise measurement of weight is only sensitive to the subject's clothing. In both surveys, subjects were wearing only undergarments and were therefore effectively nude (Laubach et al., 1977a; Gordon et al., 1989). Therefore, the observed secular trend pattern for weight cannot be explained as a subtle difference in measuring technique. Since similar trend patterns appear for other dimensions, it would seem equally inappropriate to ascribe their secular trend patterns to the influence of subtle differences in measuring technique. Some other factor must be responsible for the observed secular trend patterns.

Migration (condition 2) influences secular trend patterns by bringing new persons into the population. If these new persons have sufficiently different body dimensions, their addition to the population might be detected through their influence on mean anthropometric values. This migration effect proved useful as an explanation of the observed secular trend patterns in one racial/cultural group of men (Greiner and Gordon, 1990; 1992). However, neither group examined in this analysis showed any significant migration trend (see Table 8). Therefore, there is no evidence to suggest that migration is influencing female secular trend patterns in any way.

Cultural concepts of ideal body size and shape (condition 3) have been shown to contribute to secular trend patterns in some populations (Polednak, 1975; Takahashi, 1986; Flegal et al., 1988a). Greiner and Gordon (1990; 1992) show that the patterns of secular trend for most men in the Army are consistent with shifts in an idealized body type. A test of this hypothesis requires a suite of body measurements that can be clearly delineated as soft tissue or skeletal dimensions. The dimensions available for use in this analysis, unfortunately, are not well suited for this type of distinction.

Cultural concepts of ideal body types may, however, have less direct influence on

the anthropometric distributions of Army women via accession biases. Several researchers (Flegal et al., 1988a; Harlan et al. 1988) have shown that cultural definitions of body shape norms, and acceptable ranges of body size, vary with race/ethnicity, sex, age, socioeconomic status, and social roles. It has also been shown (Flegal et al.; 1988a; 1988b; Lasker and Mascie-Taylor, 1989; Floud et al., 1990) that cultural attitudes may have the reverse effect by channeling persons of a certain build into "appropriate" social roles. In this way, women of certain body types might be channeled into the military population. Thus, a cultural concept of the idealized woman soldier might limit the selection pool of Army applicants in a way that transcends military requirements of body size and shape. A change in this type of cultural ideal, then, could result in a change in the Army population. This cultural action, however, does not describe a reshaping of the Army population from within. Instead, this action describes a culturally determined change in the selection process used to build that population. Because this process constitutes a change in the selection process, it is better considered to be a change in sampling strategy (condition 5).

Shifts in economic status (condition 4) are thought to bring about changes in anthropometric dimensions through better access to health and nutritional resources. Changes in health and nutrition affect anthropometric dimensions through the expression of genetic potential. Improved conditions should yield greater expression of genetic potential and therefore, usually, larger anthropometric dimensions. The common assumption for the U.S. population is that economics, health, and nutrition have generally improved over time. This type of influence, however, acts primarily during the growth period that is complete, or nearly complete, when soldiers enlist. Thus shifts in the economic status of the U.S. population as a whole, and in varying degrees its racial/ethnic subsets, primarily influence the secular trends of civilian groups. Their expression in military populations occurs through the sampling of individuals from each of these subpopulations, and future projections of Army male anthropometric distributions suggest that changes in the proportion of racial/ethnic group representation over time may have greater influence on military secular trends than shifts in economic status of the civilian "parent" populations (Greiner and Gordon, 1990).

Change in factors influencing the sampling of Army members from the American population (condition 5) is perhaps the most complex contributor to secular trends in Army populations. This is largely because the sampling of women for Army service is a combination of overt and covert military accession goals *and* cultural attitudes concerning women in the military. The goals of military planners and cultural attitudes are interactive, but they do not necessarily work in concert. The power for change inherent in these events lies not in their direct relationships to anthropometric values, but rather in their ability to change the frequency with which American subpopulations are sampled for military service.

The best evidence for the influence of historical events on military population sampling is seen in the size of the female military population. Figure 3 illustrates the

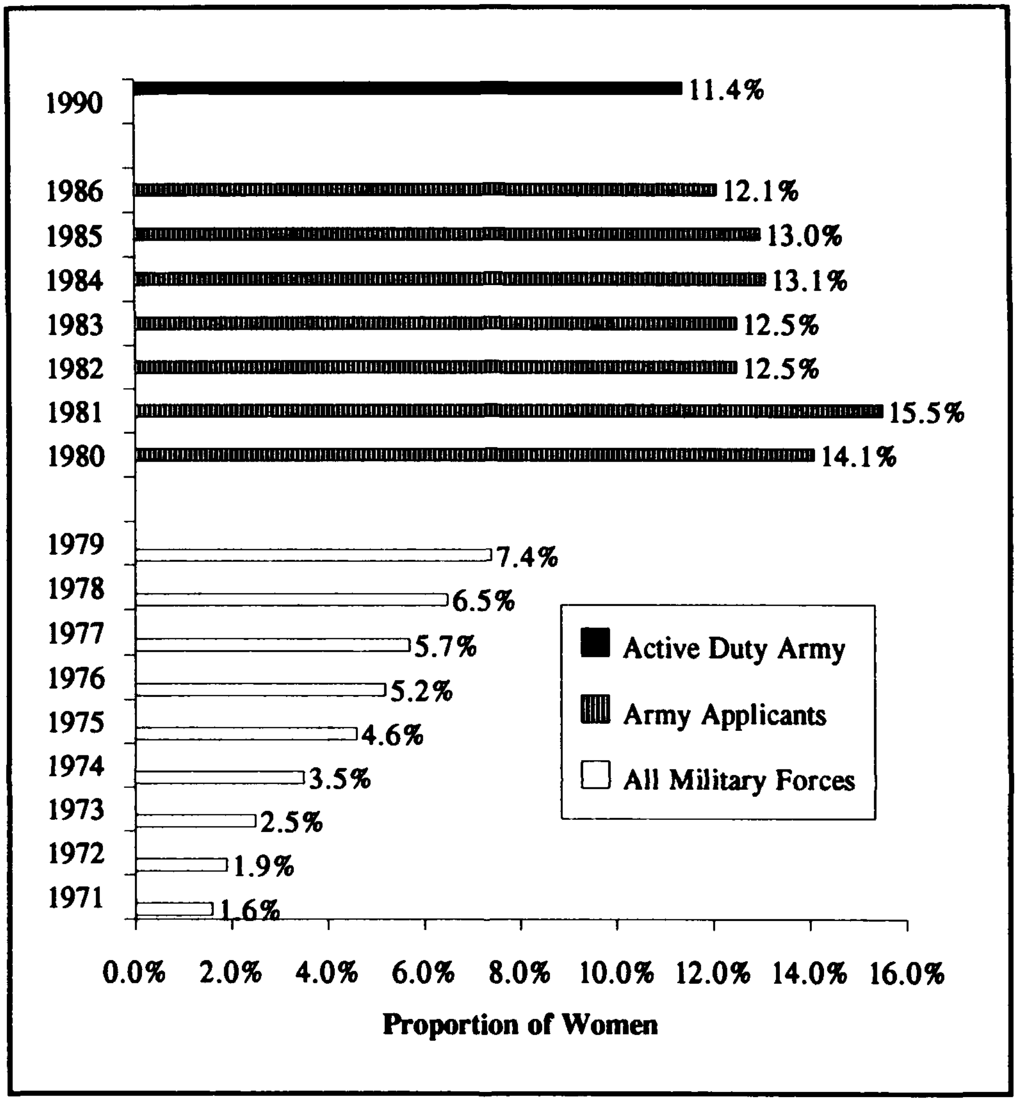

Figure 3. Recent Trends in the Participation of Women in the Military[4].

[4] These data are representational only. The 1971 - 1979 data from Binkin and Bach (1977) and White and Hosek (1982) depict the proportion of women throughout all the US military forces. The 1980 - 1986 data from the Office of the Assistant Secretary of Defense (1987) depict the proportion of women applicants for service in the Army. The 1990 data from Defense Manpower Data Center (1991) depict the proportion of women on active service in the current (December 1990) Army.

proportion of women's participation in the military for the last 20 years. Until 1968, and the lifting of the 2% cap, the military was not viewed as a practicable career option for most women. In the 1970's the growing feminist movement changed many attitudes, so the concept of a career woman was more accepted by society. The effects of these changes began to be detectable in the military in 1973 and 1975, when military women started to receive full dependency benefits and were not discharged because of pregnancy. These changes opened the military as a practicable career choice for women. The effect of these changes can be seen as the start of an increase in the proportion of women's military participation. A new population of women became available for military service and this brought about rapid growth in the proportion of Army women. Even without an associated change in anthropometric standards, the increase in the female Army population size alone may contribute to an increase in the range of population variability. Therefore, it is possible that the observed secular trends of Army women may be merely a statistical artifact of this population increase.

In a more general sense, however, a change in sampling strategy might be expected to shift the anthropometric values of a population. For example, the 1946 data set was excluded from this analysis because there was a consistent separation of its data from the other survey data sets. This separation was interpreted to be the result of the unique selection process associated with WWII and the formation in 1943 of the Women's Army Corp. Again, there is no a priori way to associate the interaction of cultural attitudes and military policies, which formed the 1946 WAC, with specific changes in anthropometric dimensions. Yet, the 1946 data set was so removed from the later data sets that it was deemed inappropriate to incorporate its data into this analysis. Using bideltoid breadth of Black women as an example (Figure 4), it appears that the secular trends within the three data sets describe three roughly parallel lines. This would imply that the underlying forces responsible for secular trends (probably acting on the general US population) are influencing these populations in the same way. The difference, therefore, among these Army populations might then be attributed to the sampling strategy used to draw them from the general population. The relative proximity of the 1977 and 1988 data sets might further be interpreted as evidence of a gradual decrease in the influence of sampling differences.

Still, the effects of a change in sampling strategy, as a root cause of secular trends, are difficult to gauge in a general application and even more difficult to test. One reason for this is that several conscious and unconscious cultural and policy decisions can affect sampling strategies in opposite directions at the same time. For example, a review of Army entrance regulations (AR40-501) shows an increase in the maximum allowable stature for women from the period of 1968 to 1988. This policy change, however, does not concur with the observed trends of decreasing stature. Even though taller women may now join the Army, some process is occurring that is bringing an even greater number of shorter women into the Army population. The questions that remain are: is stature declining because there is a negative trend in the general US population, is stature declining because of a cultural trend that redefines the sampling pool of women choosing military service, or is it a mixture of the two?

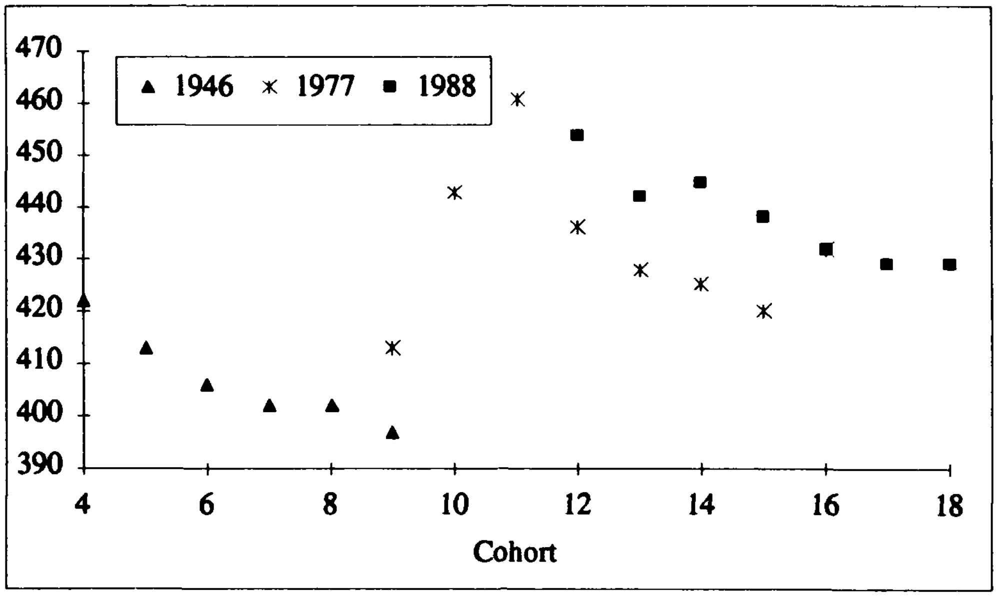

Figure 4. Scatterplot of Bideltoid Breadth (mm) vs. Birthyear Cohort for Black Women

These questions can only be addressed through a longitudinal comparison of the women eligible for military service with the women selected for military service. Unfortunately, the data needed for these comparisons are not available. While this lack of appropriate data makes a general hypothesis relating trends to shifting sampling mechanisms untestable, smaller aspects of this hypothesis can be evaluated.

As mentioned above, secular trends could result from a shift in the socioeconomic origins of military recruits. However, at best socioeconomic status is difficult to measure in a way that is both meaningful and applicable to an analysis of secular trends. One of the more commonly used surrogates for socioeconomic status is educational level (Meredith, 1976; Garn et al., 1977; Flegal et al.; 1988a; 1988b; Harlan et al., 1988). In general, these researchers found that, for women, as educational level increases stature increases and weight decreases. Applying these relationships to the patterns of secular trends reported here, the expectation is that women soldiers would show a general tendency of decreasing educational levels. This expectation could be tested, as a change in sampling strategy, by evaluating the educational levels of women in the Army.

The Army has always had an overt strategy in recruiting women based upon educational levels. Traditionally, women were required to have earned a high school diploma, or its equivalent, to be accepted into military service. In 1979 this restriction was removed and women applicants were judged solely by their ASVAB (Armed

Services Vocational Aptitude Battery) test performance (Soldier Support Center, 1980). However, in 1982 the Army began a recruiting policy that specifically targeted high school graduates, and so the requirement of a high school diploma for women was reinstated (Soldier Support Center, 1982; Binkin, 1986; Stiehm, 1989). These policy changes leave the impression that there might be a trend of increasing levels of education for Army women, which would be contrary to the expectations derived from the reported anthropometric trend patterns.

Unfortunately, the relationship between secular trends and educational trends is difficult to assess in these data because neither survey recorded any information on the educational level of its subjects. Therefore, the relationship between educational level (as an indicator of socioeconomic status) and anthropometric trends is even more tenuous. However, data are available from other sources that can be used to assess general changes in the educational levels of Army women. Table 9 presents the changes in educational levels for enlisted women in the Army. A Mantel-Haenszel chi square test was used to test for the linear relationship between educational level and year. The results of this test show that there has been no significant change in education levels for Army women. These results suggest that change in the socioeconomic origins of women soldiers does not provide the best explanation for the observed patterns of secular trend.

TABLE 9.
Change in Educational Levels of Enlisted Women in the Army[5]

Education	1973	1974	1975	1976	1977	1979	1980	1982
≤ High School	71.5%	76.1%	68.9%	64.5%	69.7%	72.4%	73.1%	75.5%
> High School	25.8%	23.9%	31.1%	35.5%	30.3%	27.6%	26.9%	24.5%
Mantel-Haenszel Chi-Square = 0.450, *df*=1, *p*=0.502								

Still, few hypotheses have been advanced that are able to explain the association between social change and anthropometric dimensions (Meredith, 1976; Flegal et al., 1988b). Most explanations that ascribe trends to the greater expression of genetic potential through increased levels of health and nutrition must assume that significant disparities exist across social levels. While these disparities do exist in some societies, the assumption of significant health and nutritional differences may not be justified for all populations. Silverstone, et al. (1969) point out that it may be a body size and

[5] Data on educational levels are from reports by the US Military Personnel Center (1974, 1976ab, 1977) and the Soldier Support Center (1979, 1980, 1982).

shape consciousness that distinguishes social groups rather than an ability to express genetic potential. Thus, there is no culturally or biologically based reason to expect trends in anthropometric dimensions to be absolutely linked to changes in socioeconomic status.

6. CONCLUSIONS

The anthropometric dimensions of women show very loose associations with time. A comparison of population values of 1977 and 1988 (Tables 10 and 11) shows that significant change has occurred for most dimensions. Yet, despite the evidence of statistically significant trend slopes, few of the examined dimensions exhibit a pattern of orderly change. In addition, none of the conventional sources of secular trend examined here is clearly consistent with these data. Although there is evidence that military "sampling" of the U.S. population may have changed over time, there is no direct basis for linking those cultural changes to the observed secular trends. In essence, we are left with the suspicion that sociodemographic processes are responsible for the observed trend patterns without the definitive ability to prove, or deny, that idea. Nevertheless, this suspicion leads to several implications about the nature of the female Army data base and about similar secular trend analyses.

First, if changes in sampling are the primary influence in forming military female secular trends, this would then be equivalent to an actual change in the study populations. Essentially, the 1977 and 1988 survey populations may have no biological commonality; they would be linked only through their common, and broad, definition of subjects as "Army women." Without the presence of biological continuity over time, traditional sources of secular change, such as improved health and nutrition, may be confounded or dwarfed by shifts in the population origins of "Army women". The flux within this study "population" suggests that the results of other studies that use similarly broad definitions might be suspect. Many investigations of secular trend focus on broadly defined populations, for example: a region or village (Hertzog, et al., 1969; Himes and Mueller, 1977; Relethford and Lees, 1981; McCullough 1982; Price, et al., 1987; Cline, et al., 1989; Sobral, 1990), college athletes (Polednak, 1975), students (Bakwin and McLaughlin, 1964; Damon, 1968; Tanner, et al. 1982; Takamura, et al., 1988) or social class (Lasker and Mascie-Taylor, 1989). This statement is not intended to question the findings reported in these studies. It merely points out that a population change within the rubric of its broad definition could drastically alter the interpretation of results. A sensitivity to population history must be part of a population definition when changes over time are the focus of the investigation.

TABLE 10.
Comparison of 1977 and 1988 Mean Values for White Women

	1977	1988	Difference
Age (yr)	23.0	26.1	3.1*
Ball of Foot Circumference (mm)	232.7	222.5	-10.2*
Bideltoid Breadth (mm)	419.6	431.1	11.5*
Buttock Circumference (mm)	956.7	968.8	12.1*
Calf Circumference (mm)	351.7	353.5	1.8
Foot Length (mm)	241.4	240.7	-0.7
Forearm-Hand Length (mm)	430.5	433.2	2.7*
Hand Breadth (mm)	77.7	78.8	1.1*
Head Breadth (mm)	145.9	144.2	-1.7*
Head Circumference (mm)	546.8	543.5	-3.3*
Head Length (mm)	186.6	186.5	-0.1
Shoulder Circumference (mm)	1001.2	1022.7	21.5*
Sitting Height (mm)	858.8	865.9	7.1*
Stature (mm)	1632.3	1632.8	0.5
Thigh Circumference (mm)	567.9	576.2	8.3*
Weight (kg)	59.3	61.7	2.4*

TABLE 11.
Comparison of 1977 and 1988 Mean Values for Black Women

	1977	1988	Difference
Age (yr)	23.0	26.1	3.1*
Ball of Foot Circumference (mm)	242.2	224.8	-17.4*
Bideltoid Breadth (mm)	423.4	433.7	10.3*
Buttock Circumference (mm)	951.3	964.7	13.4*
Calf Circumference (mm)	347.9	351.2	3.3
Foot Length (mm)	250.3	249.5	-.8
Forearm-Hand Length (mm)	452.8	456.4	3.6
Hand Breadth (mm)	80.0	80.2	0.2
Head Breadth (mm)	146.6	144.3	-2.3*
Head Circumference (mm)	557.7	549.7	-8.0*
Head Length (mm)	189.3	188.4	-0.9
Shoulder Circumference (mm)	1013.0	1031.0	18.0*
Sitting Height (mm)	826.4	835.7	9.3*
Stature (mm)	1628.3	1630.2	1.9
Thigh Circumference (mm)	573.6	586.4	12.8*
Weight (kg)	60.2	62.4	2.2*

* Difference is significant at the .05 level or better after Bonferroni correction for 16 *t*-tests.

Second, many studies seek to contrast men and women, based on their anthropometric dimensions, to ascertain biological affinities. The Army anthropometric data base lends itself as an obvious resource for these types of studies. However, the men and women of the Army may not represent comparable populations. Again, if the culturally determined processes that build the Army population are acting differently for men and women, then these processes would also affect the results of a comparison between these two groups. Any comparisons made between Army men and women would reveal biological differences based upon culture as much as they will reveal biological differences based upon sex. By extension, the influence of culturally based differential selection processes might also affect the construction of racial/cultural groups within the Army population. Therefore, the Army population may not be the best source of data for a study that aims to address questions of biological differences among population groups. This observation does not invalidate contrasts that aim to create sizing systems for the Army. It does, however, urge caution when drawing biological inferences based on those perceived differences.

Finally, this analysis was unable to identify specific processes that are likely to be responsible for the observed patterns of secular trends. Without a firm understanding of why anthropometric change is occurring, there can be no confidence in a projection of those trends into the future. Some regularity in the population membership must be established before past trends can be applied as predictors of the future. This means that, despite the construction of statistically significant secular trend regression models, specific predictions of anthropometric values for future populations of Army women cannot be justified. Furthermore, recent events have produced debate over defining a role for women in combat and the responsibilities of parents in the military (Schrof, 1989; Abrams, 1992). Legal, policy, and cultural decisions on these issues may be seen as the next major milestones that could affect the sampling of Army women from the general U.S. population. Future secular trends may thus depend, in part, on the outcome of these debates.

Secular trends are indeed occurring within the population of Army women. As yet, however, there is no way to reliably anticipate the direction and magnitude of these changes. Indeed, the changes over time seem so erratic that use of the term "trends" may be too strong. This situation, coupled with the sense of upcoming population perturbation and then perhaps some stability, argue the need for additional data. A series of mini-anthropometric surveys, spaced at approximately five-year intervals, could provide the data needed to test several of the hypotheses advanced in this report. More important, however, if the female Army population is no longer overtly influenced by changes in sampling strategy, then these mini-surveys will provide a basis for constructing secular trend models that may be able to predict anthropometric values of Army women into the future. Until that time, designers must wait for the data. Therefore, current anthropometric values should be retained and used for all future equipment designs.

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APPENDIX A

AN ALTERNATIVE METHOD OF DERIVING SECULAR TRENDS

The erratic trend patterns derived in this report might result in questions about the appropriateness of the quantitative method. The crux of this method was the analysis of age-related change as a distinct phenomenon. Those results were then used to correct for the effects of aging within the data sample. Therefore, derived trend patterns could have been unsuitably influenced by these age-correction factors. If this method is inappropriate for the analysis of secular trends, then the results of this report and the report on secular trends in men (Greiner and Gordon, 1990) would be unsound. This possibility was tested by deriving secular trend rates in a way that is independent from the effects of aging. Both the male and female data sets were analyzed for two dimensions, stature and weight. Different calculation methods would not be expected to result in precise matches for secular trend rates. However, if the methods are equally sound, trend rates should approximate one another in both their magnitude and direction.

Data for this analysis come from the 1977 and 1988 anthropometric surveys of Army women and the 1966 and 1988 anthropometric surveys of Army men (White and Churchill, 1971; Laubach et al., 1977a; 1977b; Gordon et al., 1989). The data within each survey were grouped by race (Whites and Blacks) into seven age groups: $\leq$20, 21-25, 26-30, 31-35, 36-40, 41-45, and 46-50. Individuals older than 50 years were excluded from this analysis because of the paucity of appropriate data in the 1966 and 1977 survey data sets. Secular trends were plotted for each age group by connecting the mean value of each group between the surveys (see Figures A-1 to A-8).

The plots presented in these figures connect groups of individuals of the same age measured in the different survey years. Therefore, these plots show individual secular trend rates that are independent of any age-related influences. Ideally, anthropometric dimensions that are unaffected by aging would create a smooth, seemingly, single line that would connect all the age groups. None of the examples presented here, however, would be expected to reflect that ideal. Instead, weight and stature are well known to change during the aging process (Chumlea et al., 1988; Cline et al., 1989; Chandler and Bock, 1991). Therefore, for age-affected dimensions one would expect to see a series of parallel lines where the shift between lines describes the aging trend. Close approximations of this expected pattern are seen in the plots of weight for all groups. These patterns can be interpreted as showing a consistent secular trend pattern for weight in all the sex and age groups. To a lesser extent, the trend patterns displayed for the stature of White and Black men (Figures A-5 and A-7) also reflect the pattern expected with age-affected dimensions. Still, each line for male stature shows a basic agreement in the magnitude and direction of secular change. The plots of women's stature (Figures A-1 and A-3), however, show very little resemblance

to the expected pattern. No regular pattern of secular change in stature can be easily discerned from the age-group plots for either White or Black women.

For each of the plots presented, separate secular trend rates can be calculated. The difference between the mean values for an age-group describes the amount of secular change that has occurred during the interval between anthropometric surveys. Dividing this value by the interval between surveys (11 years for women, 22 years for men) describes the rate of change per year. Calculating this value for each age-group and then calculating the mean of those seven values creates a statement of the average rate of secular trend per year for the entire population (Hyde, 1980). Finally, multiplying the average value by 5 creates a statement of the rate of secular trend per five-year period that should be comparable to the previously reported rates of change per cohort. Tables A-1 and A-2 show the results of these calculations and their comparison to previously reported results.

In all instances, the separately derived values of secular trend rates were similar; that is, their descriptions of the magnitude and direction of secular trend were roughly equivalent. These comparisons show that similar secular trend patterns are derived from the two alternative methods. This means that the secular trend patterns described in this report are not likely to be artifacts of their calculation method. The best interpretation is that the described secular trend patterns are genuine.

TABLE A-1

Alternative Calculation of Women's Secular Trends[1]

White Women's Stature (mm):			
Age	1977	1988	Slope
≤20	1626.1	1624.6	-0.14
21-25	1635.0	1635.5	0.05
26-30	1631.5	1640.4	0.81
31-35	1645.2	1627.3	-1.63
36-40	1665.4	1634.7	-2.79
41-45	1635.3	1651.1	1.44
46-50	1632.7	1629.9	-0.25
Mean Slope	= -0.36 mm/yr		
New Trend	= -1.80 mm/5 yr		
Old Trend	= -1.31 mm/5 yr		

White Women's Weight (kg)			
Age	1977	1988	Slope
≤20	58.62	59.89	0.12
21-25	58.63	60.94	0.21
26-30	60.90	62.37	0.13
31-35	61.75	62.32	0.05
36-40	64.76	66.33	0.14
41-45	65.56	67.96	0.22
46-50	67.22	62.83	-0.40
Mean Slope	= 0.07 kg/yr		
New Trend	= 0.34 kg/5 yr		
Old Trend	= -0.08 kg/5 yr		

Black Women's Stature (mm):			
Age	1977	1988	Slope
≤20	1624.7	1628.8	0.37
21-25	1636.2	1629.9	-0.57
26-30	1621.9	1630.4	0.77
31-35	1611.2	1627.9	1.52
36-40	1678.8	1645.7	-3.01
41-45	1663.5	1627.3	-3.29
46-50	1583.0	1584.2	0.11
Mean Slope	= -0.59 mm/yr		
New Trend	= -2.93 mm/5 yr		
Old Trend	= -0.59 mm/5 yr		

Black Women's Weight (kg)			
Age	1977	1988	Slope
≤20	58.96	59.92	0.09
21-25	59.88	60.86	0.09
26-30	61.57	63.26	0.15
31-35	62.69	64.52	0.17
36-40	65.59	68.10	0.23
41-45	83.50	68.39	-1.37
46-50	68.47	65.78	-0.24
Mean Slope	= -0.13 kg/yr		
New Trend	= -0.63 kg/5 yr		
Old Trend	= -1.52 kg/5 yr		

[1] "Old" trend rates are those reported in the body of this report; "new" trend rates are those calculated using the alternative method presented in this Appendix.

TABLE A-2
Alternative Calculation of Men's Secular Trends[2]

White Men's Stature (mm):			
Age	1966	1988	Slope
≤20	1746.0	1760.7	0.67
21-25	1751.9	1758.0	0.28
26-30	1754.4	1776.7	1.01
31-35	1757.6	1756.4	-0.05
36-40	1730.2	1764.0	1.54
41-45	1757.0	1762.9	0.27
46-50	1704.4	1756.5	2.37
Mean Slope = 0.87 mm/yr			
New Trend = 4.35 mm/5 yr			
Old Trend = 3.71 mm/5 yr			

White Men's Weight (kg)			
Age	1966	1988	Slope
≤20	70.30	75.35	0.23
21-25	72.95	77.44	0.20
26-30	74.91	79.72	0.22
31-35	77.92	80.69	0.13
36-40	78.62	82.86	0.19
41-45	77.77	82.08	0.20
46-50	79.31	86.40	0.32
Mean Slope = 0.21 kg/yr			
New Trend = 1.06 kg/5 yr			
Old Trend = 1.36 kg/5 yr			

Black Men's Stature (mm):			
Age	1966	1988	Slope
≤20	1746.6	1752.0	0.25
21-25	1749.9	1756.8	0.31
26-30	1737.8	1759.6	0.99
31-35	1733.9	1761.4	1.25
36-40	1732.2	1745.1	0.59
41-45	1736.4	1761.9	1.16
46-50	1775.0	1720.5	-2.48
Mean Slope = 0.30 mm/yr			
New Trend = 1.48 mm/5 yr			
Old Trend = 1.46 mm/5 yr			

Black Men's Weight (kg)			
Age	1966	1988	Slope
≤20	69.84	74.66	0.22
21-25	74.17	77.56	0.15
26-30	77.07	80.33	0.15
31-35	78.34	82.18	0.17
36-40	80.77	82.40	0.07
41-45	80.84	83.26	0.11
46-50	90.54	85.03	-0.25
Mean Slope = 0.09 kg/yr			
New Trend = 0.44 kg/5 yr			
Old Trend = 0.77 kg/5 yr			

[2] "Old" trend rates are those reported in the body of this report; "new" trend rates are those calculated using the alternative method presented in this Appendix.

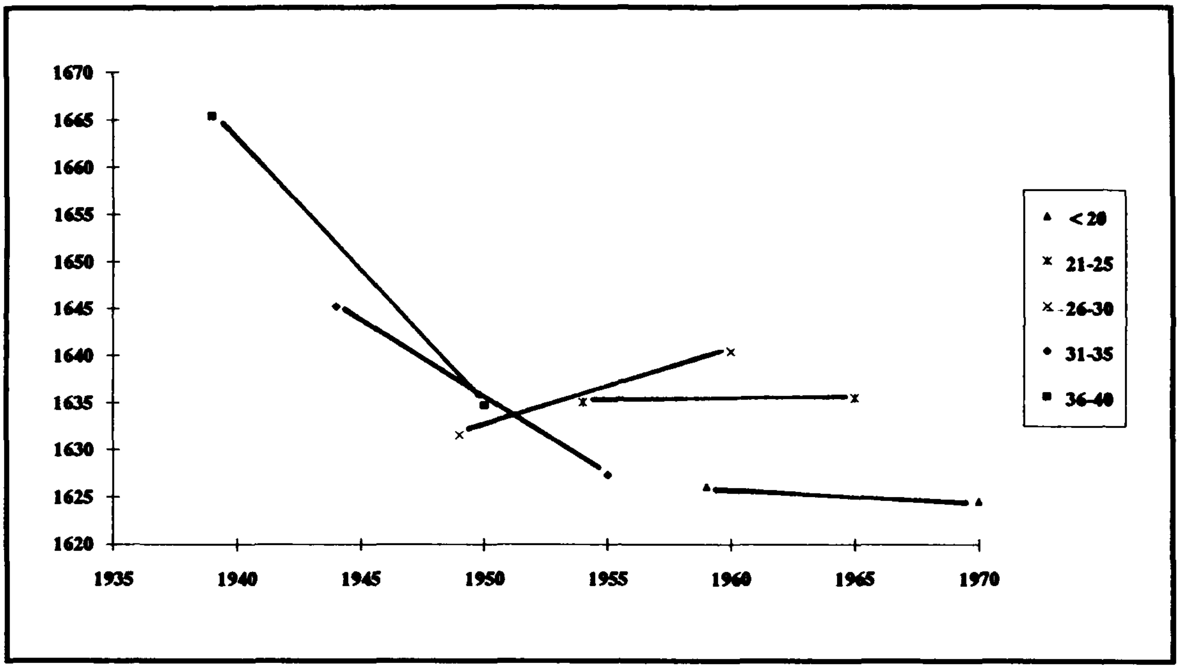


Figure A-1. Alternative Secular Trend Plot of White Women's Stature (mm)

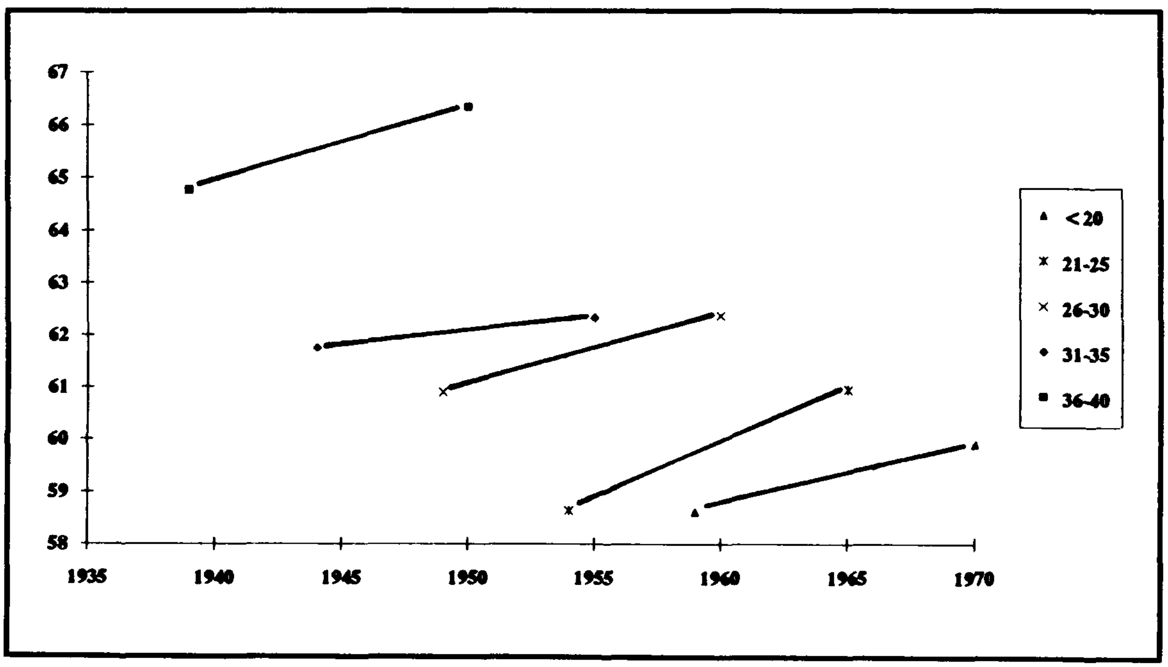


Figure A-2. Alternative Secular Trend Plot of White Women's Weight (kg)

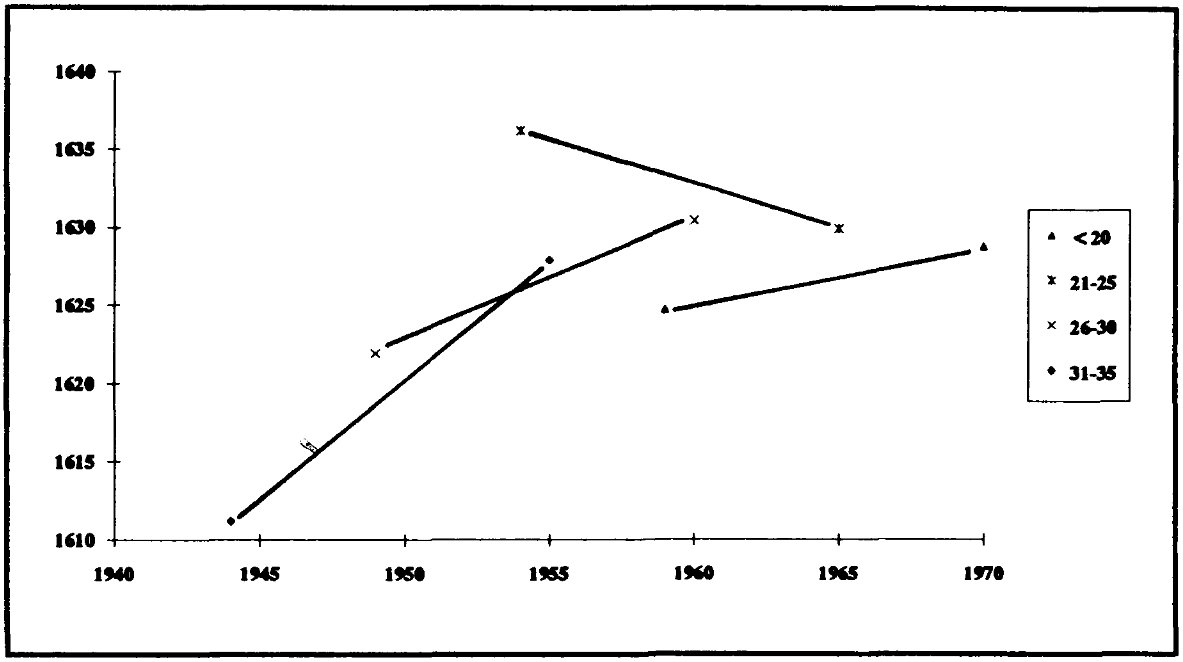


Figure A-3. Alternative Secular Trend Plot of Black Women's Stature (mm)

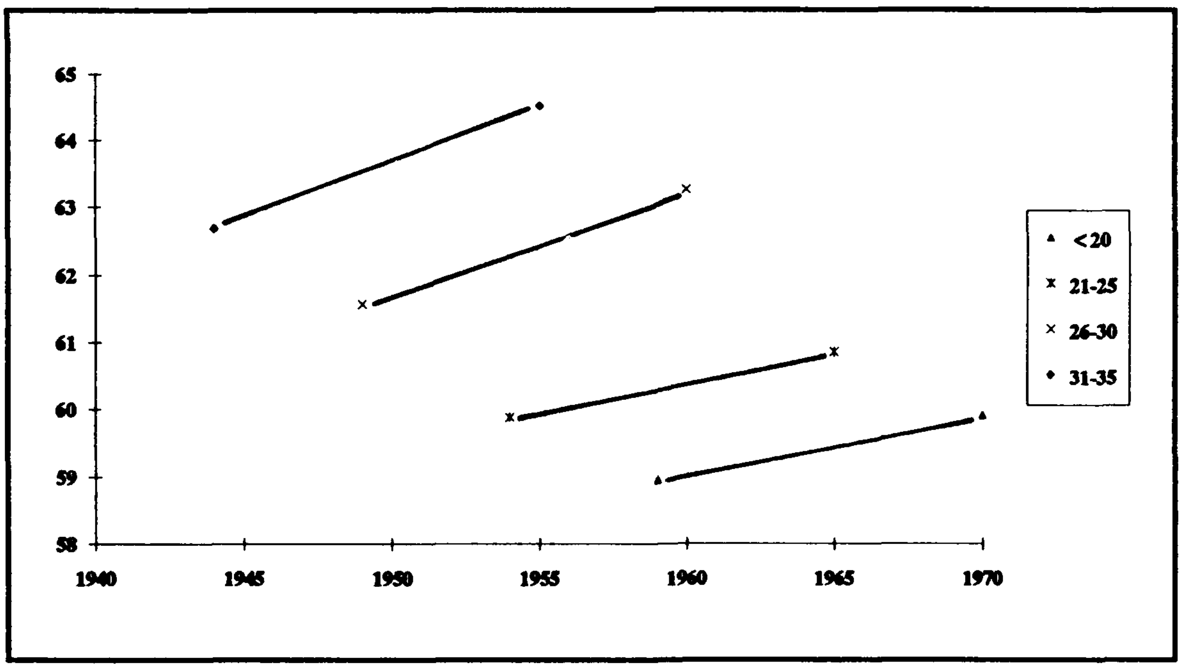


Figure A-4. Alternative Secular Trend Plot of Black Women's Weight (kg)

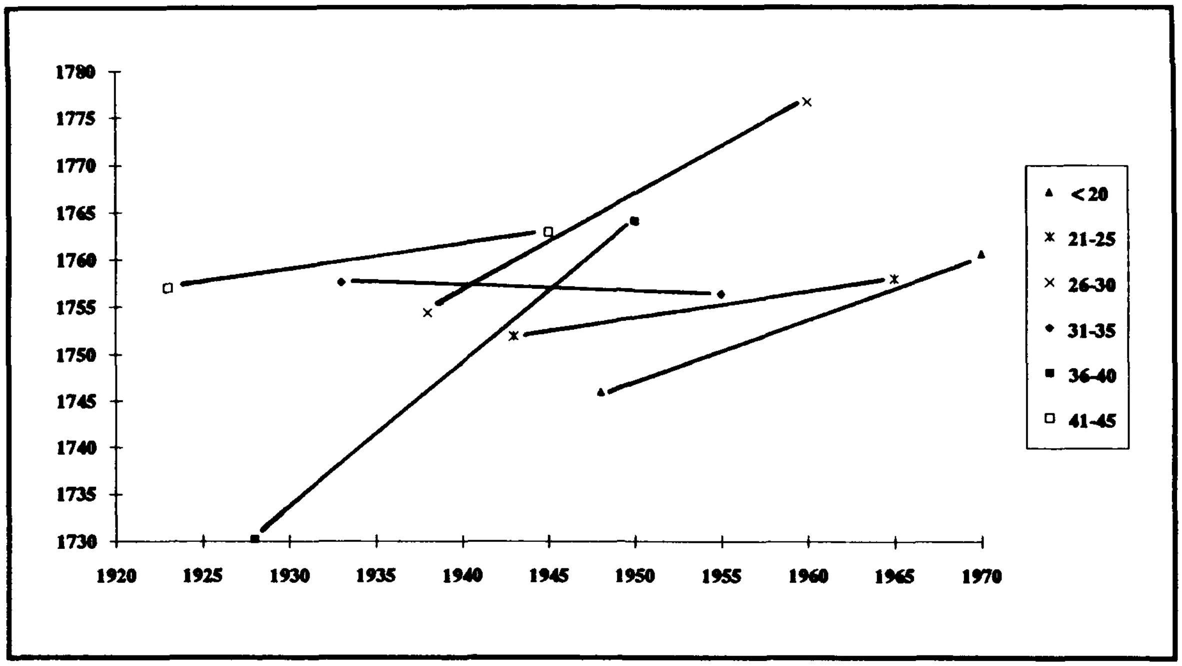


Figure A-5. Alternative Secular Trend Plot of White Men's Stature (mm)

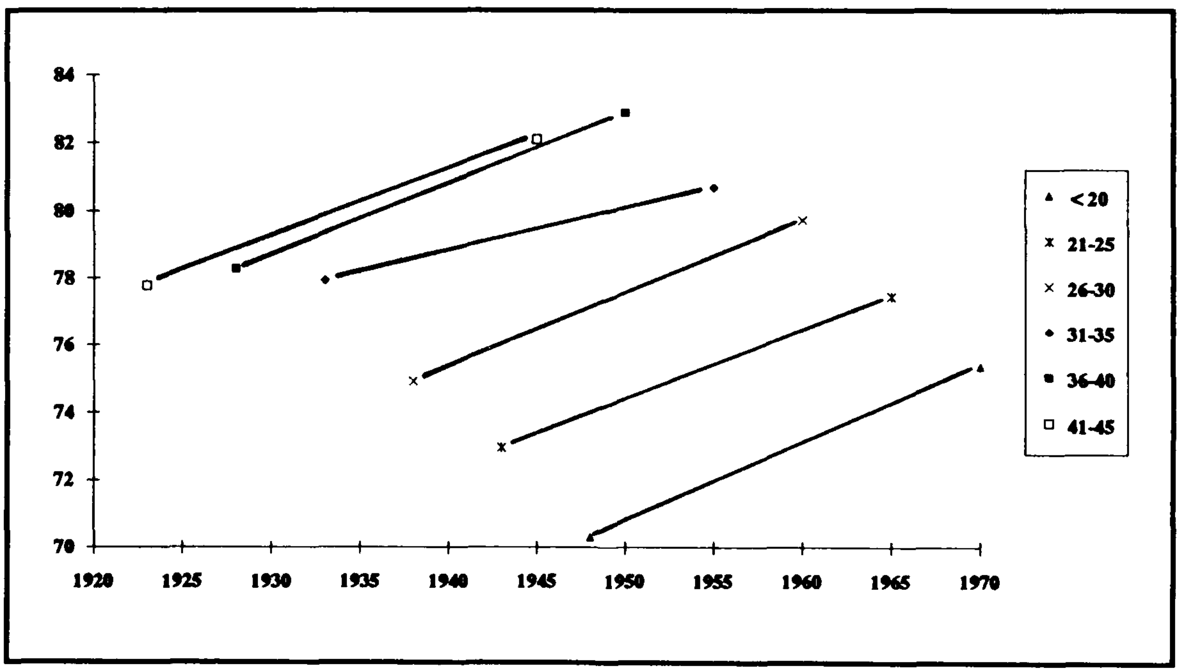


Figure A-6. Alternative Secular Trend Plot of White Men's Weight (kg)

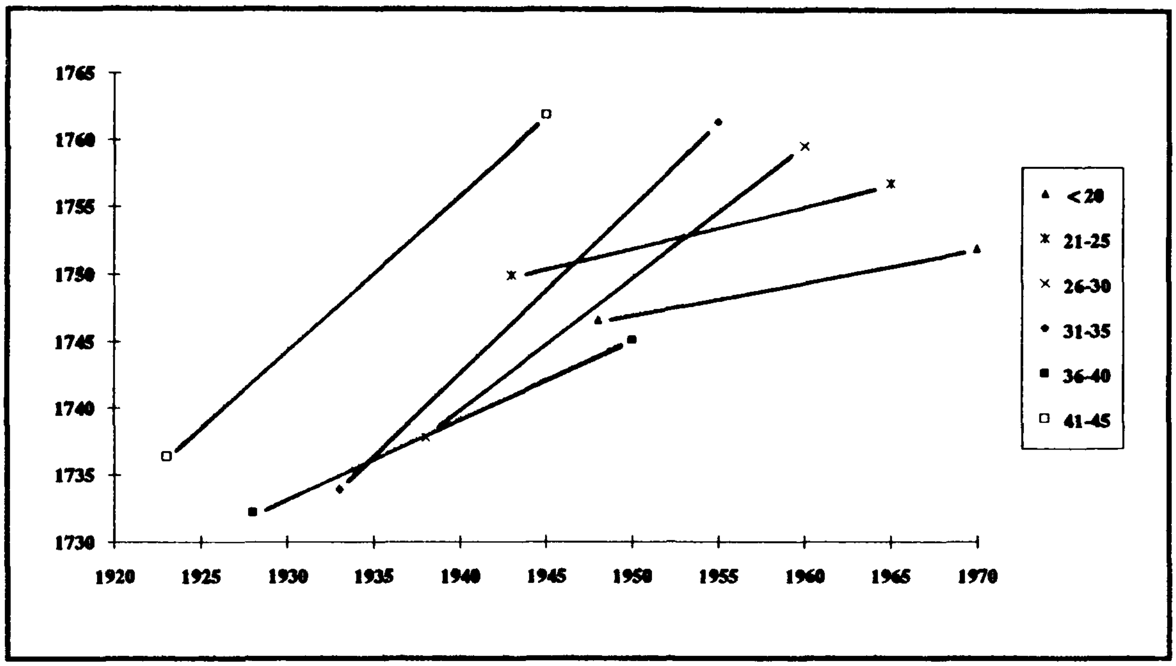


Figure A-7. Alternative Secular Trend Plot of Black Men's Stature (mm)

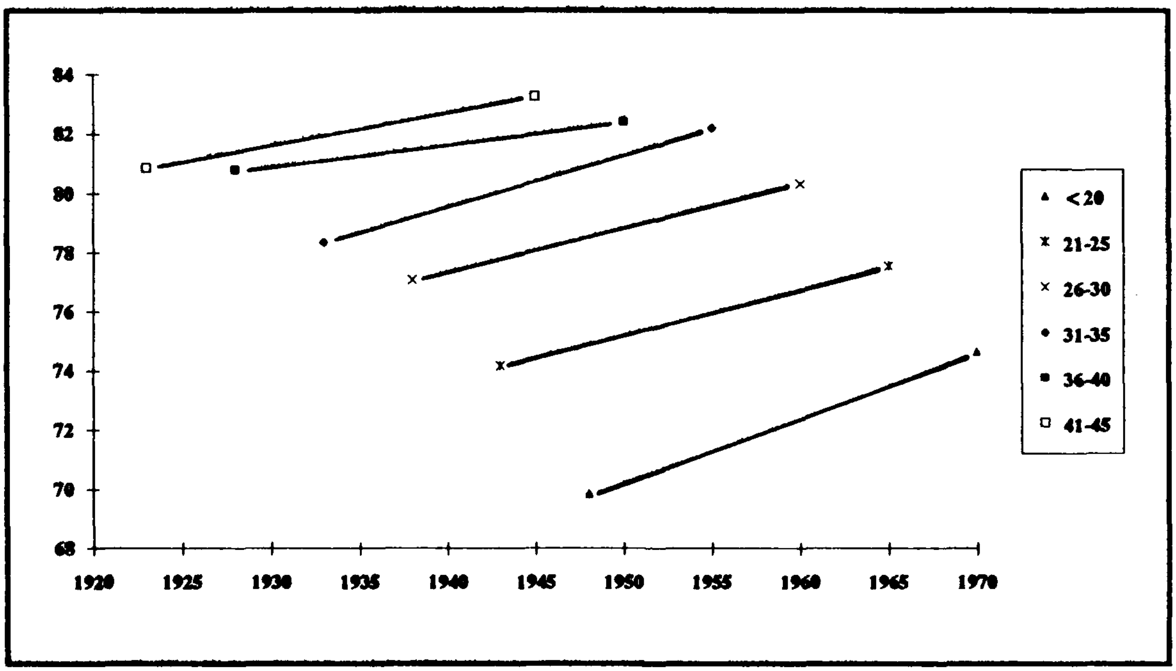


Figure A-8. Alternative Secular Trend Plot of Black Men's Weight (kg)

APPENDIX B

DIMENSION MEANS BY BIRTHYEAR COHORT

TABLE B-1.
Cohort Means for Ball of Foot Circumference, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	203			2			
3	215			3			
4	218			4	230		
5	217			5	227		
6	219			6	224		
7	218			7	224		
8	218			8	223		
9	218	234		9	224	243	
10		237		10		232	
11		235	233	11		253	
12		233	228	12		242	227
13		234	225	13		243	227
14		231	223	14		241	228
15		233	223	15		242	226
16		239	222	16		252	226
17			222	17			223
18			220	18			222

TABLE B-2.
Cohort Means for Bideltoid Breadth, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	395			2			
3	395			3			
4	398			4	422		
5	396			5	413		
6	397			6	406		
7	396			7	402		
8	396			8	402		
9	394	426		9	397	413	
10		435		10		443	
11		429	420	11		461	
12		425	438	12		436	454
13		422	441	13		428	442
14		419	434	14		425	445
15		418	431	15		420	438
16		424	431	16		432	432
17			430	17			429
18			424	18			429

TABLE B-3.
Cohort Means for Buttock Circumference, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	925			2			
3	954			3			
4	965			4	998		
5	957			5	998		
6	952			6	982		
7	949			7	963		
8	949			8	953		
9	948	997		9	958	1008	
10		1013		10		1002	
11		997	978	11		1073	
12		978	1001	12		989	996
13		974	1022	13		979	994
14		959	992	14		950	1000
15		949	979	15		940	981
16		953	964	16		995	965
17			958	17			948
18			951	18			935

TABLE B-4.
Cohort Means for Calf Circumference, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9		360		9		390	
10		357		10		362	
11		365	347	11		357	
12		349	355	12		354	351
13		352	360	13		351	354
14		351	357	14		347	353
15		351	354	15		346	353
16		364	353	16		359	353
17			352	17			349
18			353	18			346

TABLE B-5.
Cohort Means for Foot Length, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	248			2			
3	234			3			
4	238			4	239		
5	238			5	246		
6	239			6	242		
7	238			7	247		
8	239			8	246		
9	239	244		9	251	260	
10		245		10		245	
11		249	246	11		256	
12		245	244	12		250	246
13		242	243	13		249	251
14		241	240	14		251	251
15		241	240	15		250	250
16		243	242	16		253	250
17			241	17			249
18			237	18			249

TABLE B-6.
Cohort Means for Forearm-Hand Length, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9		426		9		455	
10		436		10		441	
11		434	426	11		461	
12		437	437	12		444	452
13		430	437	13		456	461
14		431	433	14		455	458
15		430	431	15		452	456
16		427	434	16		454	457
17			433	17			455
18			428	18			456

TABLE B-7.
Cohort Means for Hand Breadth, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	70.0			2			
3	76.8			3			
4	76.9			4	80.3		
5	76.2			5	77.7		
6	77.2			6	77.2		
7	76.9			7	78.4		
8	76.8			8	78.1		
9	76.0	77.0		9	78.5	78.0	
10		80.0		10		78.5	
11		79.2	79.0	11		84.0	
12		78.2	80.3	12		79.7	81.6
13		77.6	80.5	13		81.2	81.6
14		77.4	79.3	14		79.9	81.2
15		77.7	79.0	15		79.7	80.6
16		79.1	78.7	16		84.3	80.7
17			78.6	17			79.5
18			78.1	18			79.2

TABLE B-8.
Cohort Means for Head Breadth, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	151			2			
3	146			3			
4	147			4	147		
5	147			5	144		
6	146			6	145		
7	146			7	144		
8	146			8	142		
9	145	147		9	143	148	
10		150		10		148	
11		147	144	11		155	
12		147	146	12		149	147
13		147	147	13		148	146
14		146	145	14		148	146
15		145	145	15		146	144
16		145	144	16		149	144
17			144	17			144
18			143	18			145

TABLE B-9.
Cohort Means for Head Circumference, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	553			2			
3	553			3			
4	554			4	564		
5	553			5	565		
6	550			6	562		
7	551			7	554		
8	551			8	551		
9	545	547		9	550	562	
10		546		10		567	
11		546	544	11		583	
12		551	554	12		556	554
13		547	548	13		562	552
14		548	543	14		559	554
15		546	544	15		556	551
16		545	544	16		559	550
17			543	17			548
18			542	18			550

TABLE B-10.
Cohort Means for Head Length, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	182			2			
3	183			3			
4	184			4	186		
5	184			5	171		
6	184			6	189		
7	183			7	186		
8	184			8	186		
9	182	185		9	185	192	
10		184		10		194	
11		186	186	11		196	
12		187	189	12		188	188
13		186	186	13		191	190
14		187	186	14		189	190
15		186	186	15		189	189
16		186	187	16		193	188
17			186	17			188
18			186	18			188

TABLE B-11.
Cohort Means for Shoulder Circumference, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9		1025		9		985	
10		1041		10		1080	
11		1028	1010	11		1101	
12		1020	1051	12		1035	1090
13		1007	1051	13		1030	1054
14		998	1028	14		1021	1060
15		999	1022	15		1003	1040
16		1018	1022	16		1019	1028
17			1020	17			1020
18			1015	18			1018

TABLE B-12.
Cohort Means for Sitting Height, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	875			2			
3	834			3			
4	836			4	835		
5	837			5	810		
6	838			6	804		
7	838			7	805		
8	838			8	808		
9	832	839		9	826	838	
10		867		10		814	
11		863	855	11		848	
12		868	862	12		820	830
13		862	875	13		836	846
14		861	866	14		827	840
15		856	869	15		824	837
16		858	868	16		843	834
17			864	17			835
18			855	18			833

TABLE B-13.
Cohort Means for Stature, in mm

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	1685			2			
3	1605			3			
4	1609			4	1655		
5	1617			5	1622		
6	1621			6	1597		
7	1623			7	1610		
8	1624			8	1618		
9	1617	1608		9	1620	1626	
10		1652		10		1599	
11		1648	1614	11		1679	
12		1650	1644	12		1610	1609
13		1636	1650	13		1635	1642
14		1636	1631	14		1626	1635
15		1628	1630	15		1629	1630
16		1626	1640	16		1614	1629
17			1630	17			1630
18			1611	18			1633

TABLE B-14.
Cohort Means for Thigh Circumference, in mm

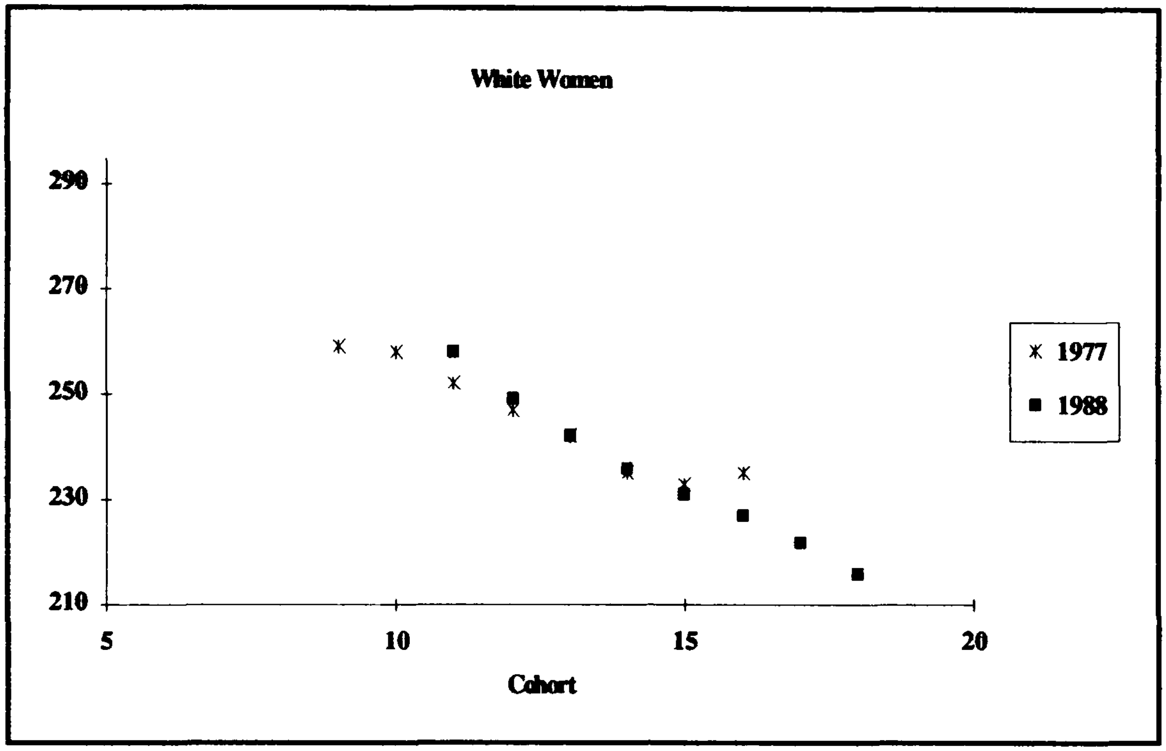
White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9		593		9		621	
10		591		10		621	
11		586	576	11		638	
12		572	591	12		597	597
13		579	604	13		586	600
14		567	590	14		575	609
15		565	580	15		567	596
16		581	575	16		596	587
17			569	17			576
18			572	18			568

TABLE B-15.
Cohort Means for Weight, in kg

White Females				Black Females			
Cohort	1946	1977	1988	Cohort	1946	1977	1988
2	57.2			2			
3	59.2			3			
4	61.0			4			
5	60.2			5	66.0		
6	59.4			6	62.9		
7	59.0			7	58.5		
8	58.9			8	58.5		
9	58.4	64.7		9	60.2	67.6	
10		67.2		10		70.3	
11		65.2	60.5	11		74.4	
12		61.8	66.8	12		63.8	66.5
13		60.9	68.4	13		62.9	66.8
14		59.4	63.9	14		60.4	67.0
15		58.5	62.5	15		59.0	64.1
16		61.1	61.4	16		63.9	62.3
17			60.4	17			60.3
18			59.1	18			59.2

APPENDIX C

SCATTERPLOTS OF AGE-ADJUSTED MEANS VS. BIRTHYEAR COHORT



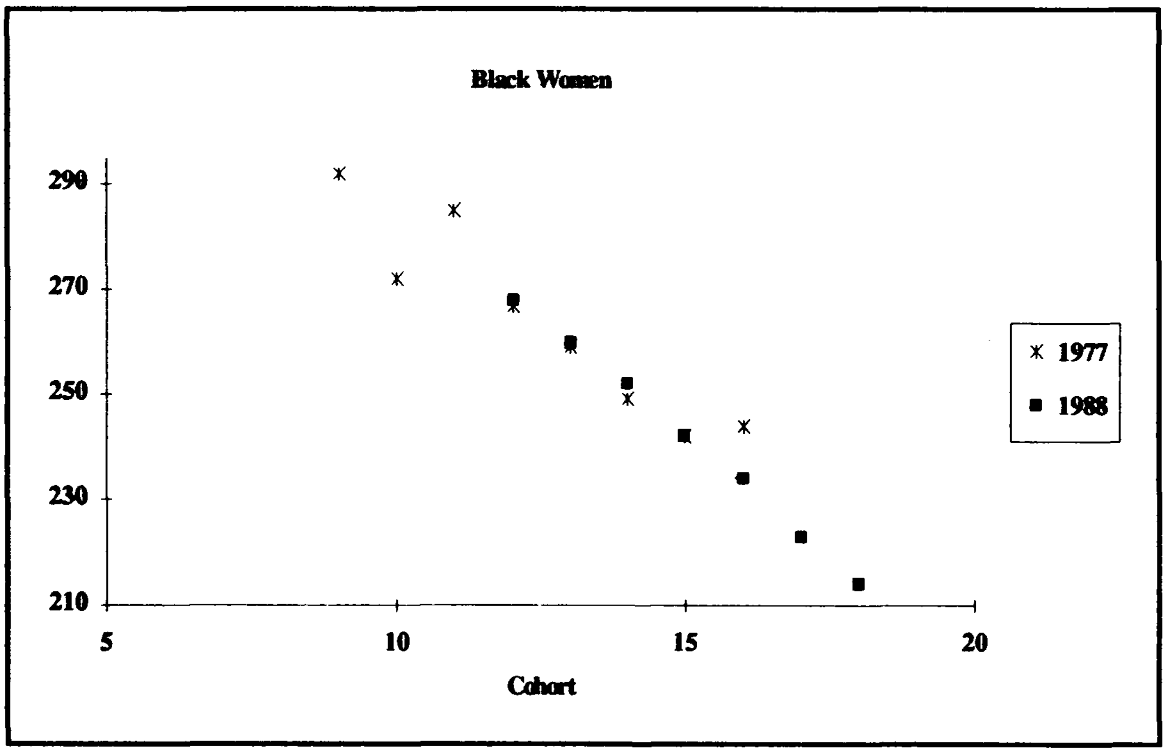
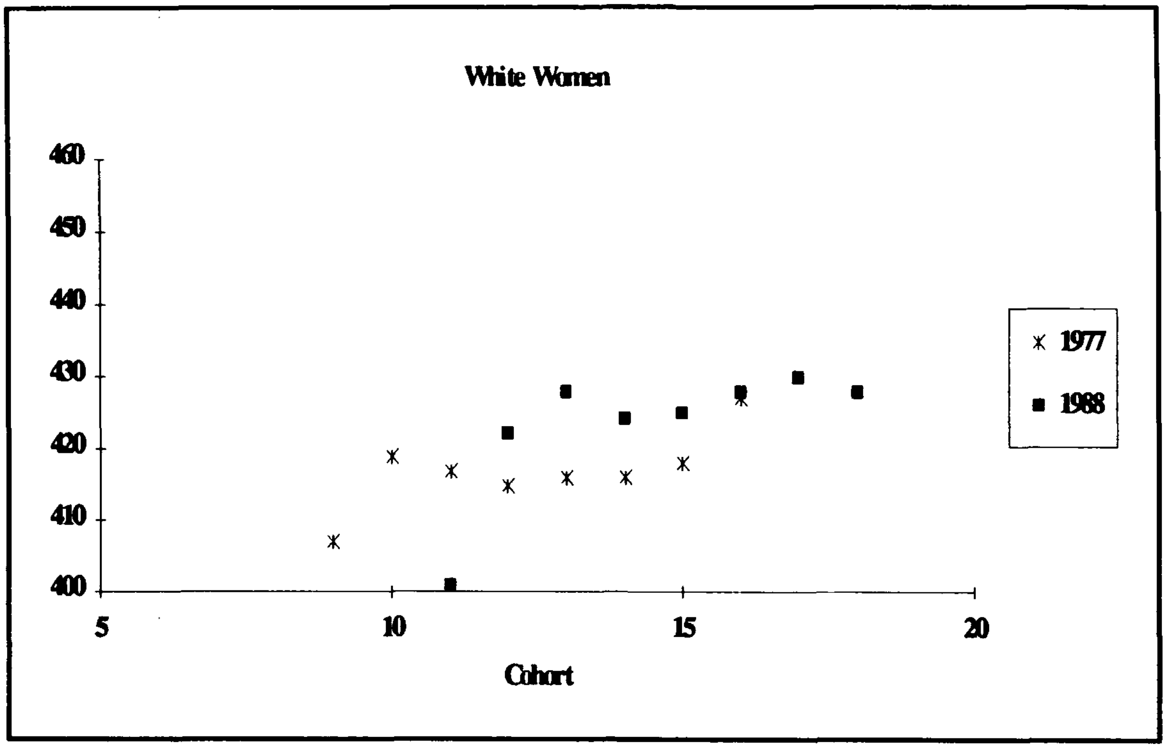


Figure C-1. Ball of Foot Circumference (mm) vs. Birthyear Cohort



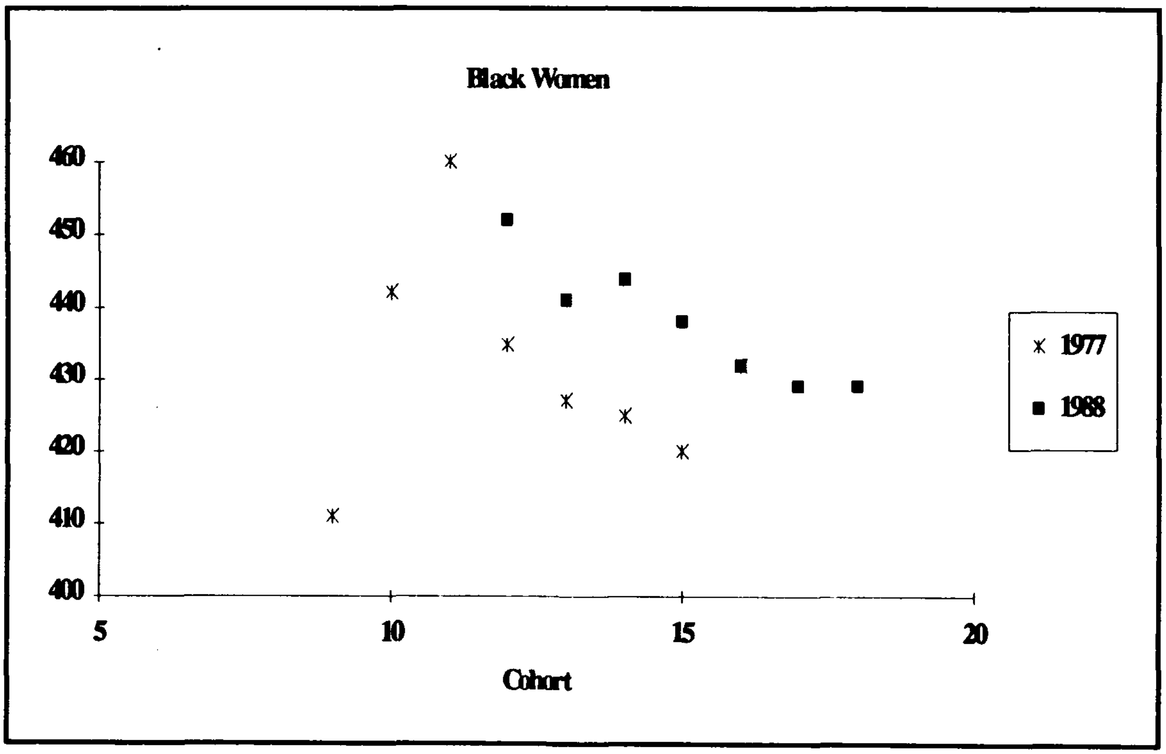
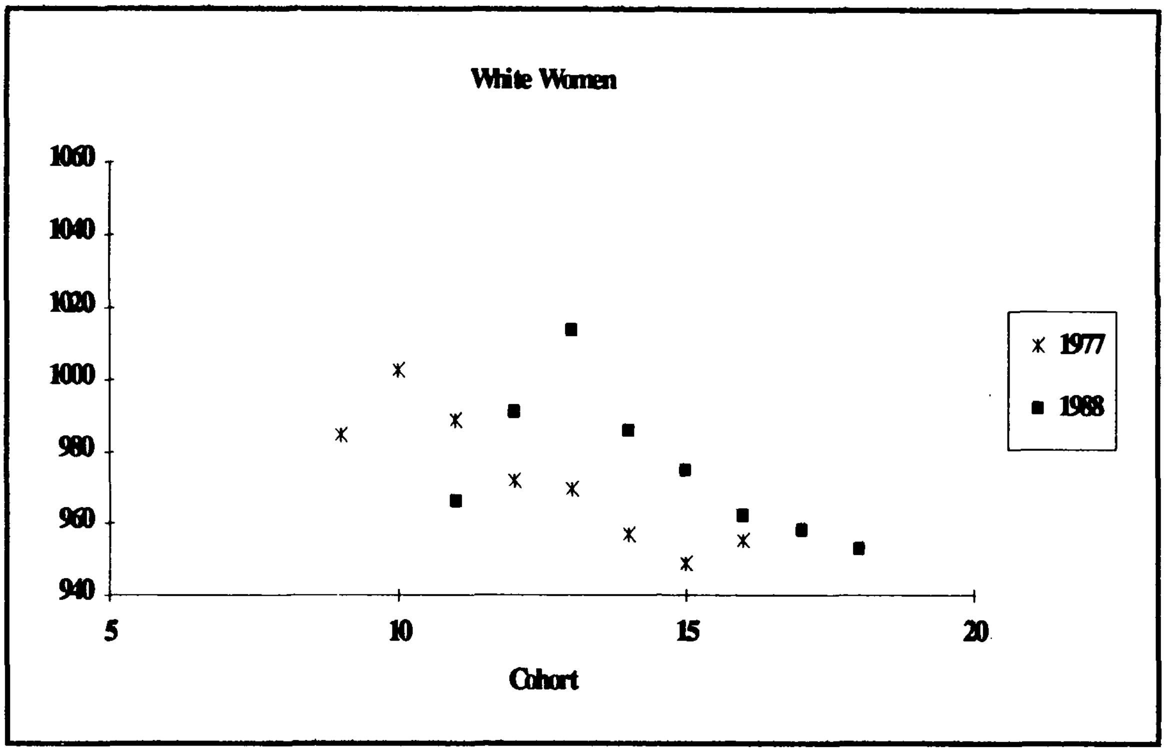


Figure C-2. Bideltoid Breadth (mm) vs. Birthyear Cohort



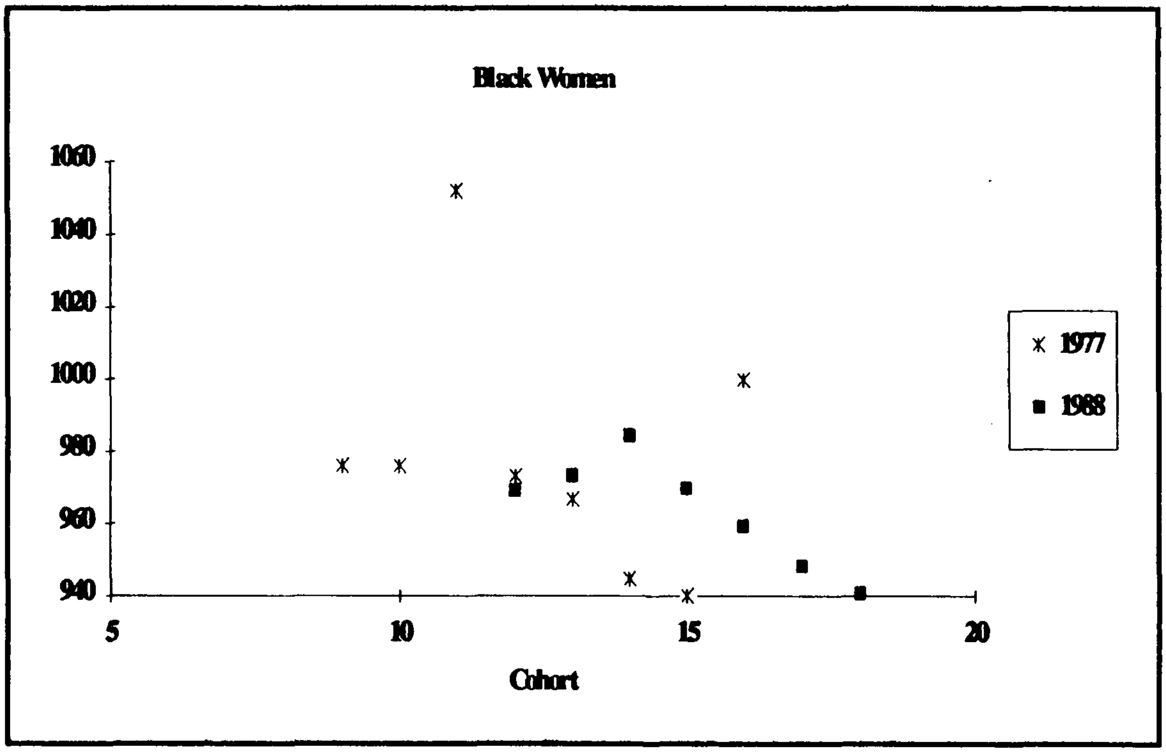
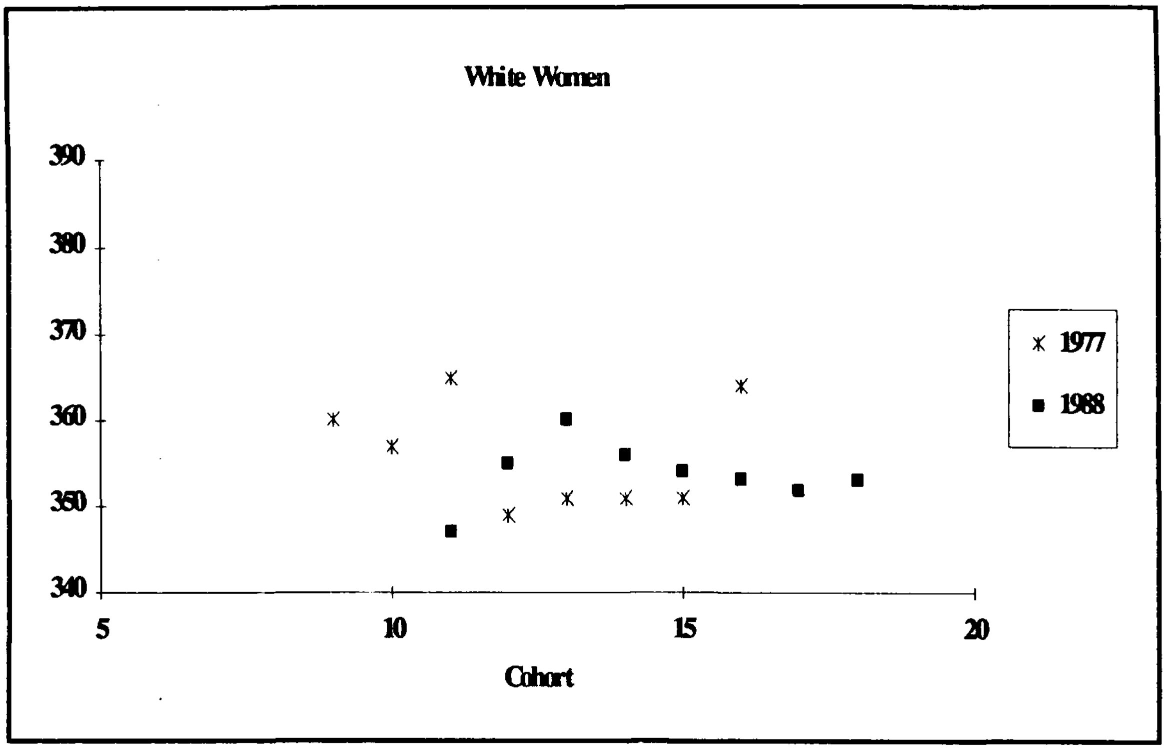


Figure C-3. Buttock Circumference (mm) vs. Birthyear Cohort



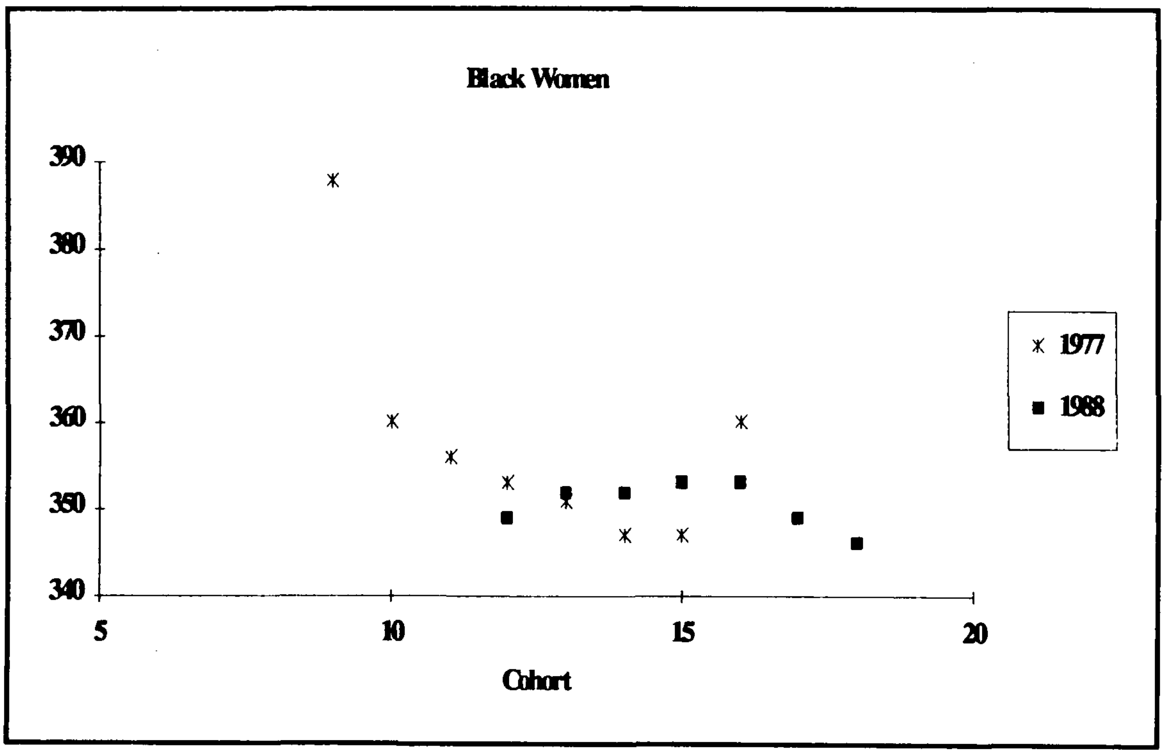
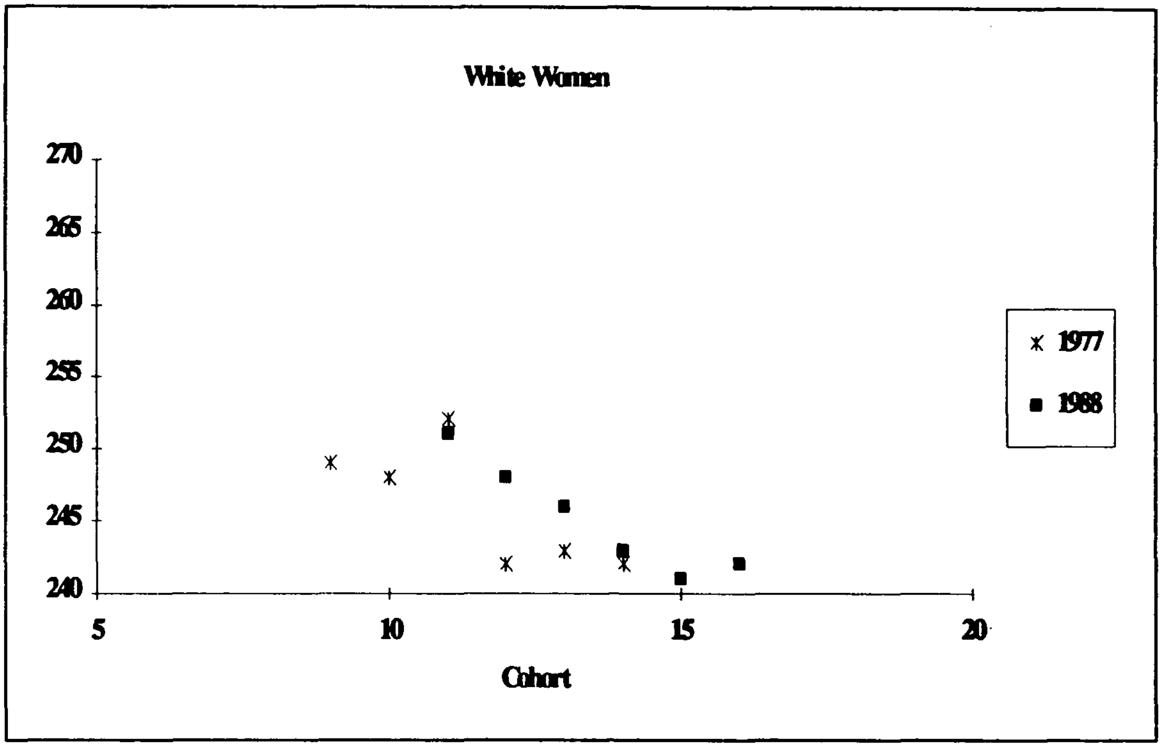


Figure C-4. Calf Circumference (mm) vs. Birthyear Cohort



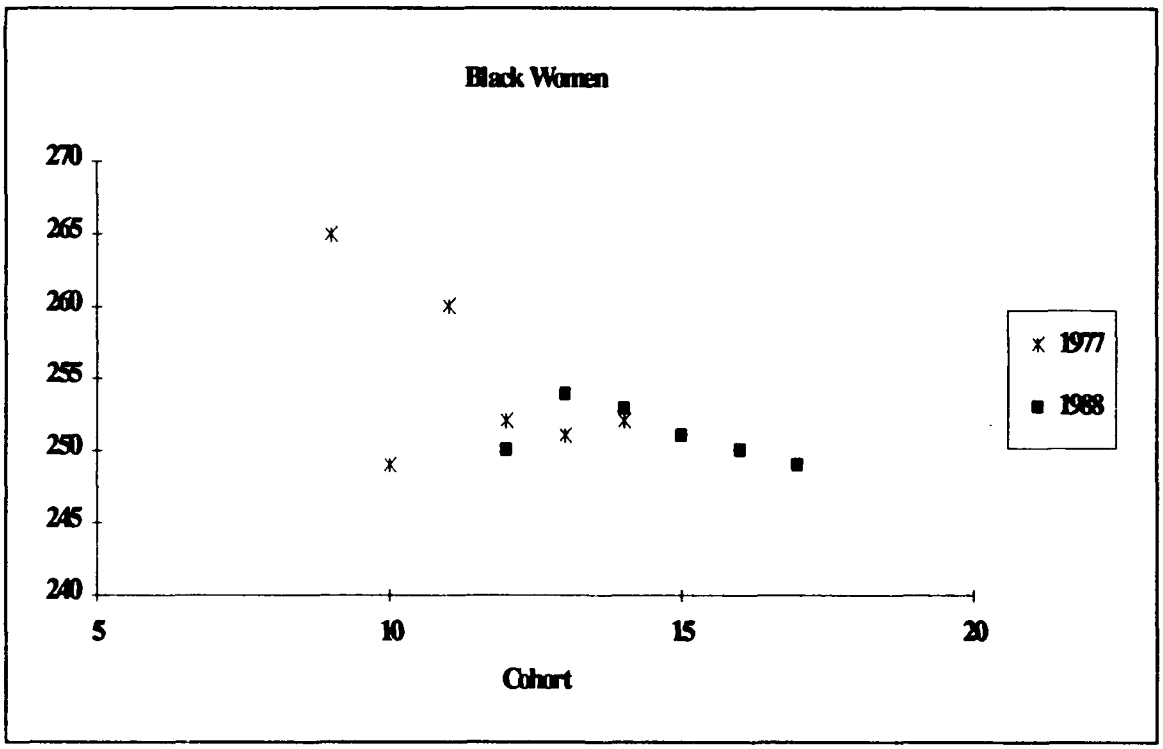
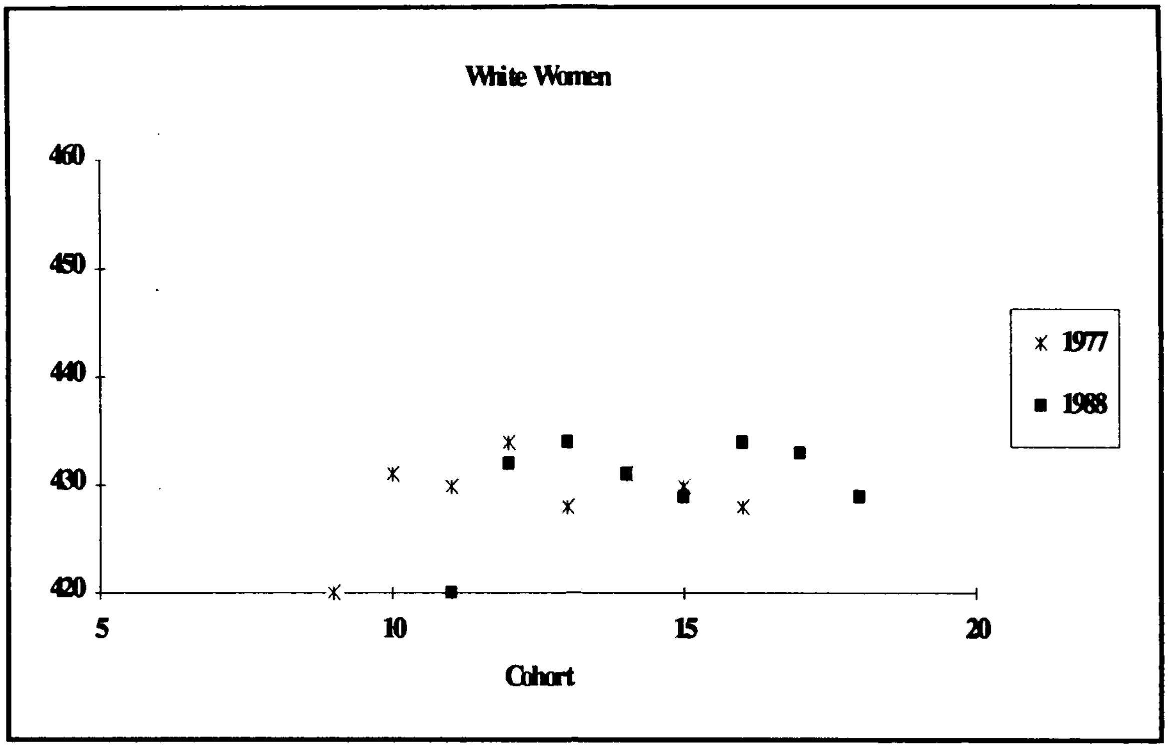


Figure C-5. Foot Length (mm) vs. Birthyear Cohort



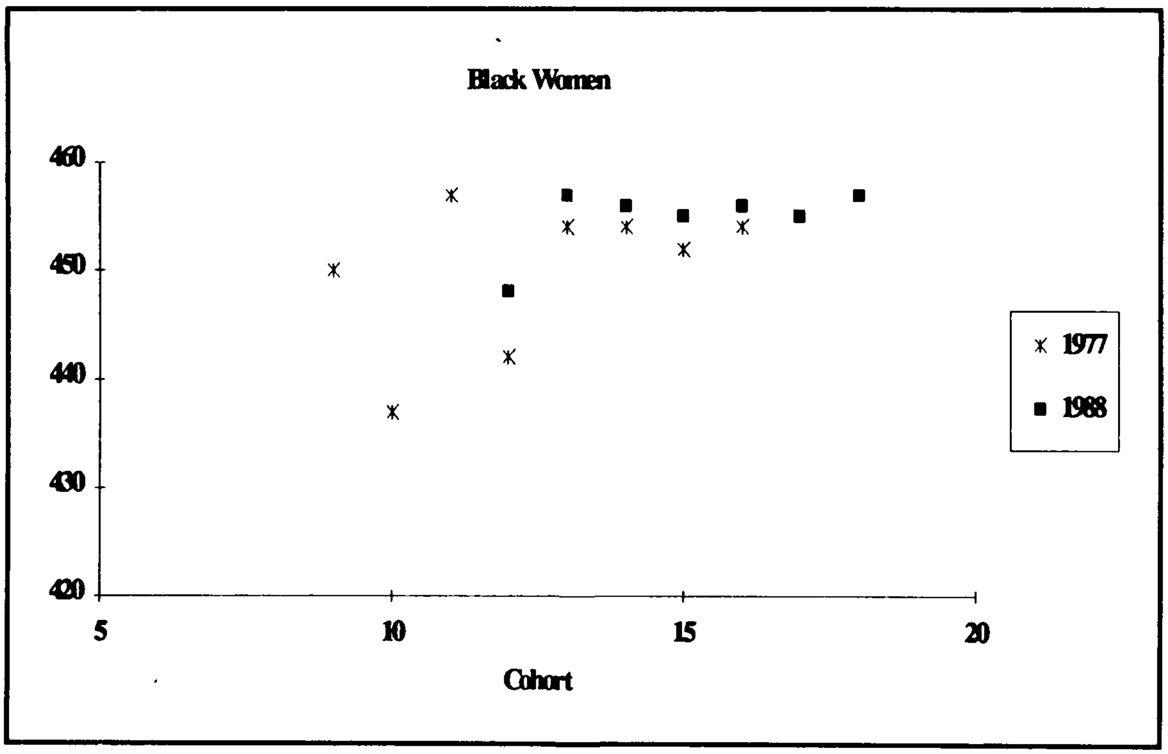


Figure C-6. Forearm-Hand Length (mm) vs. Birthyear Cohort

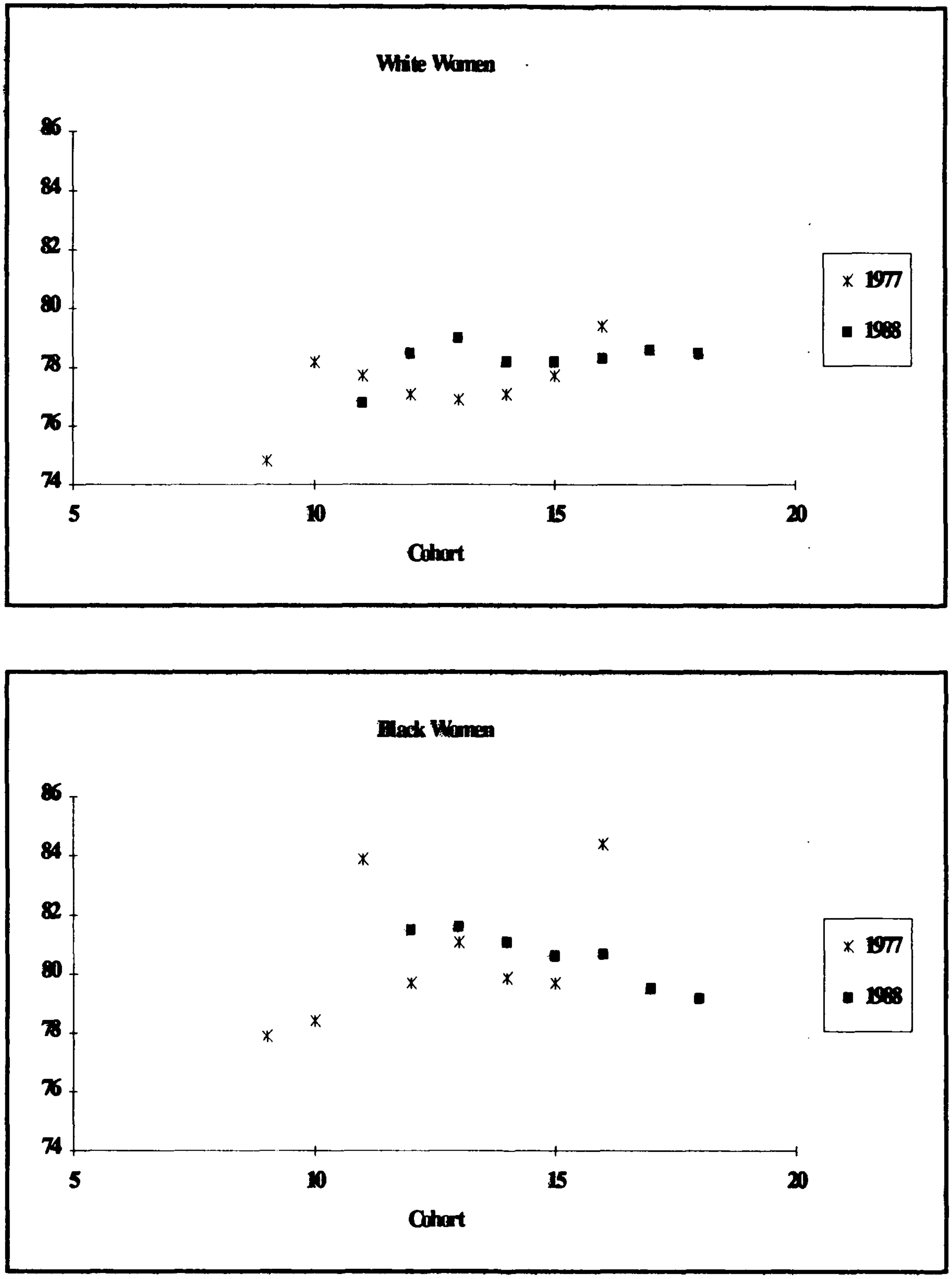
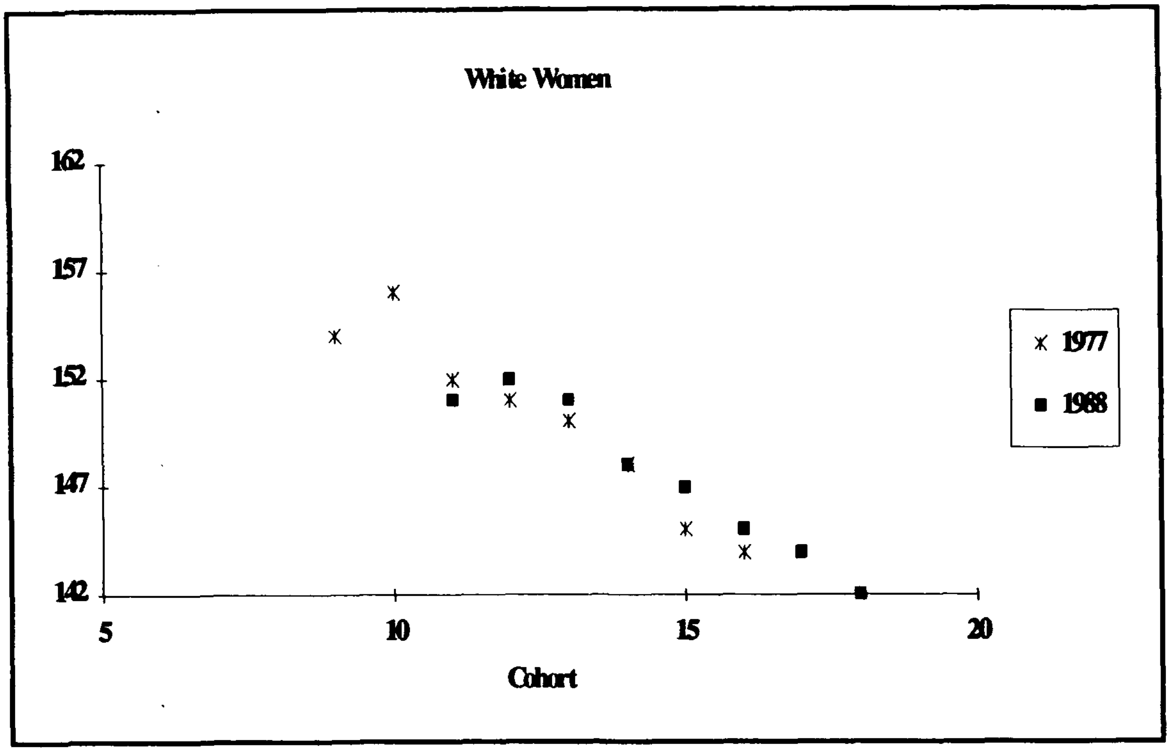


Figure C-7. Hand Breadth (mm) vs. Birthyear Cohort



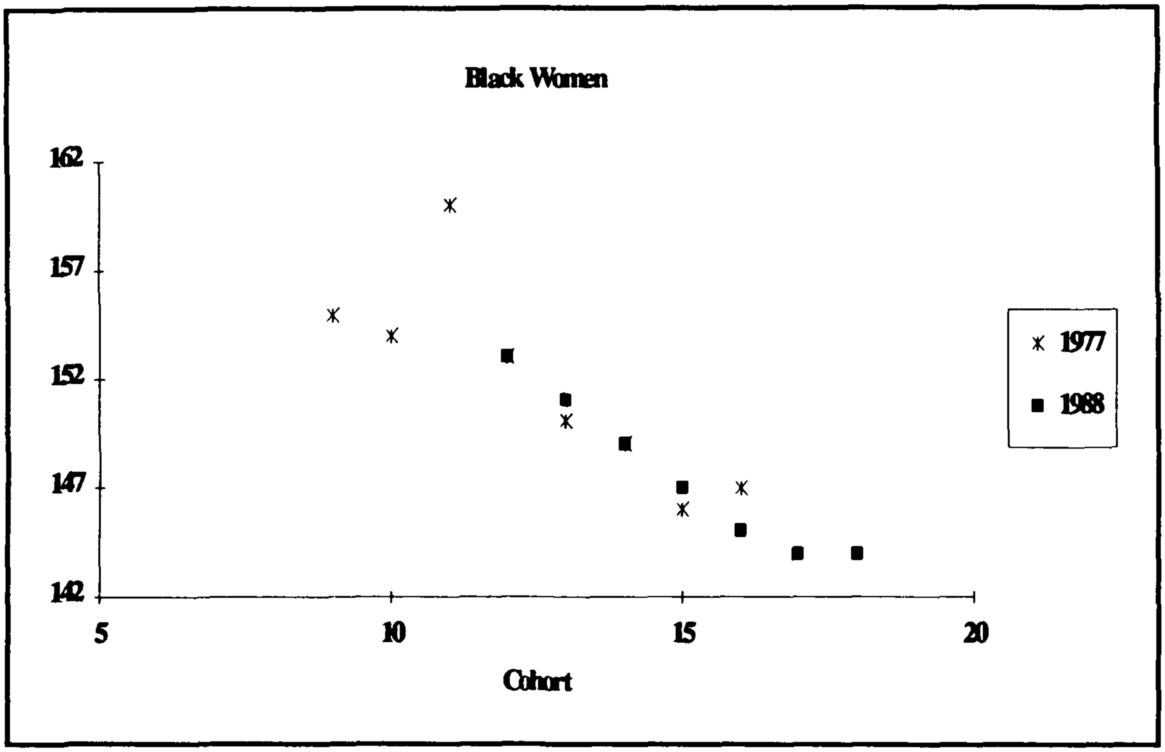
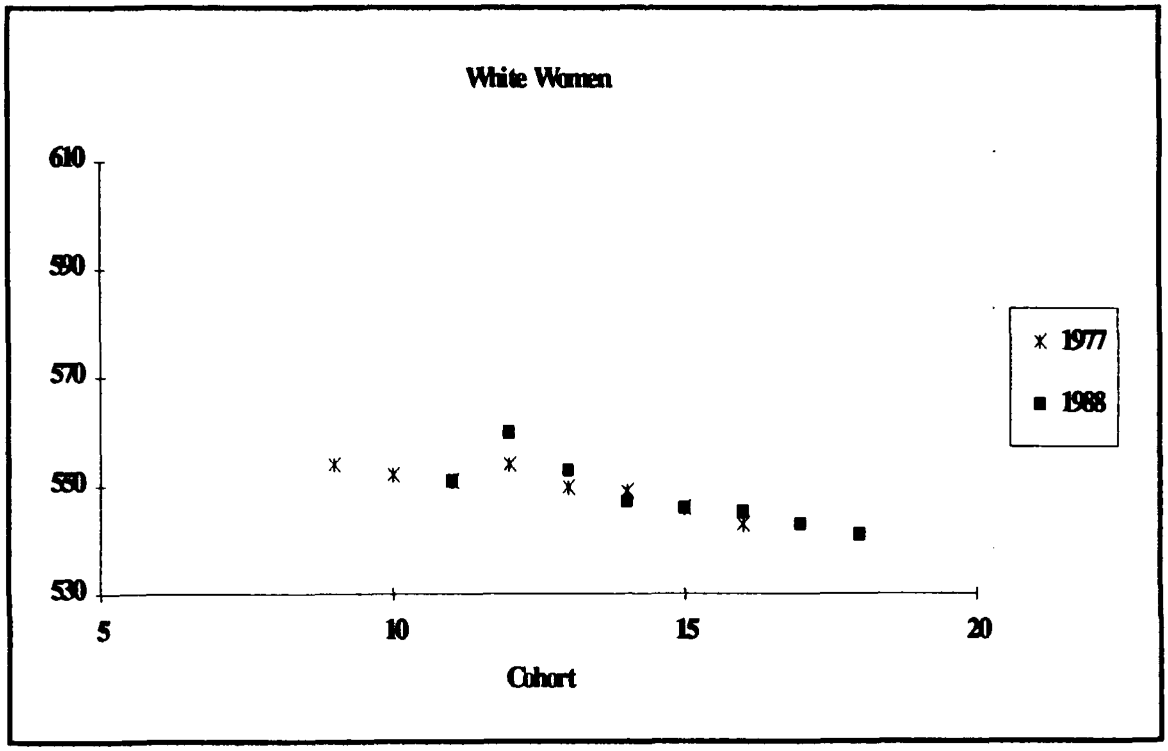


Figure C-8. Head Breadth (mm) vs. Birthyear Cohort



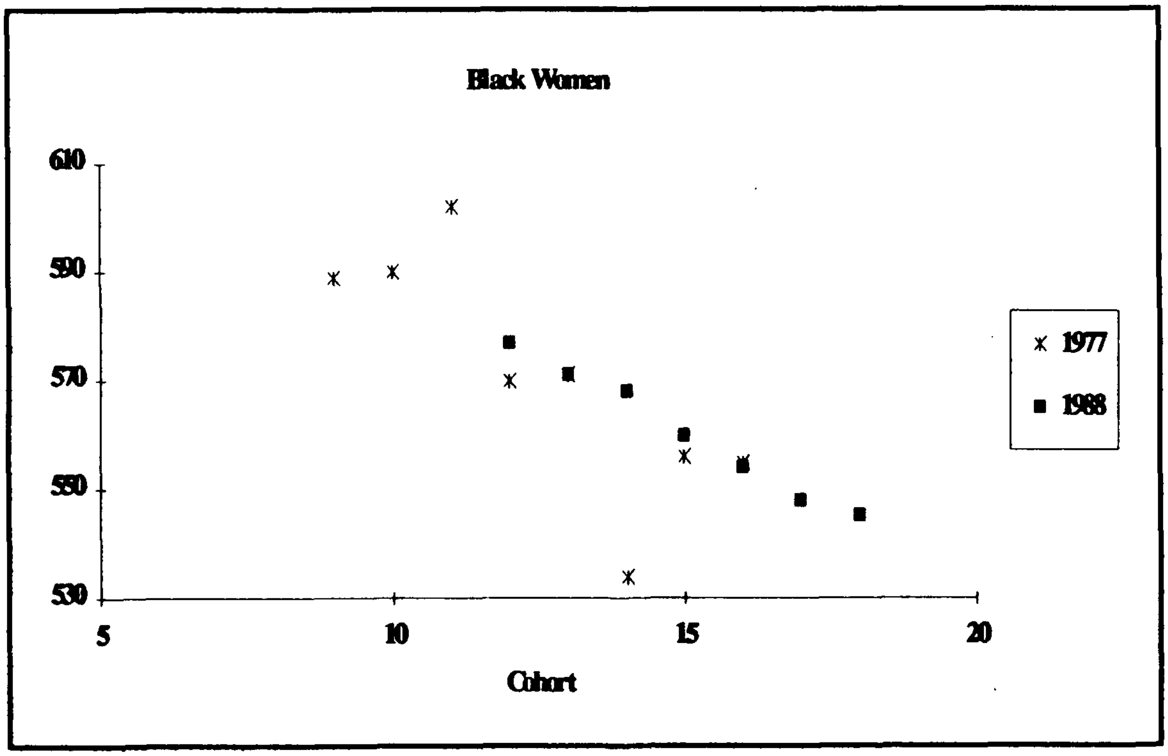
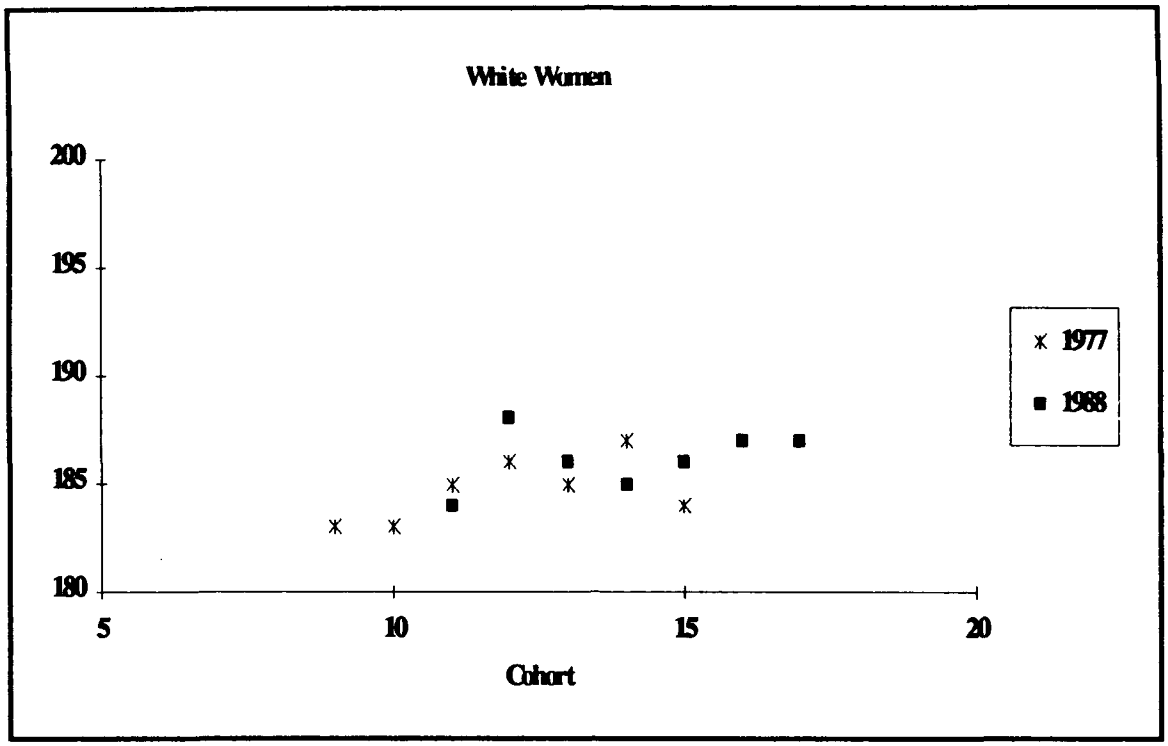


Figure C-9. Head Circumference (mm) vs. Birthyear Cohort



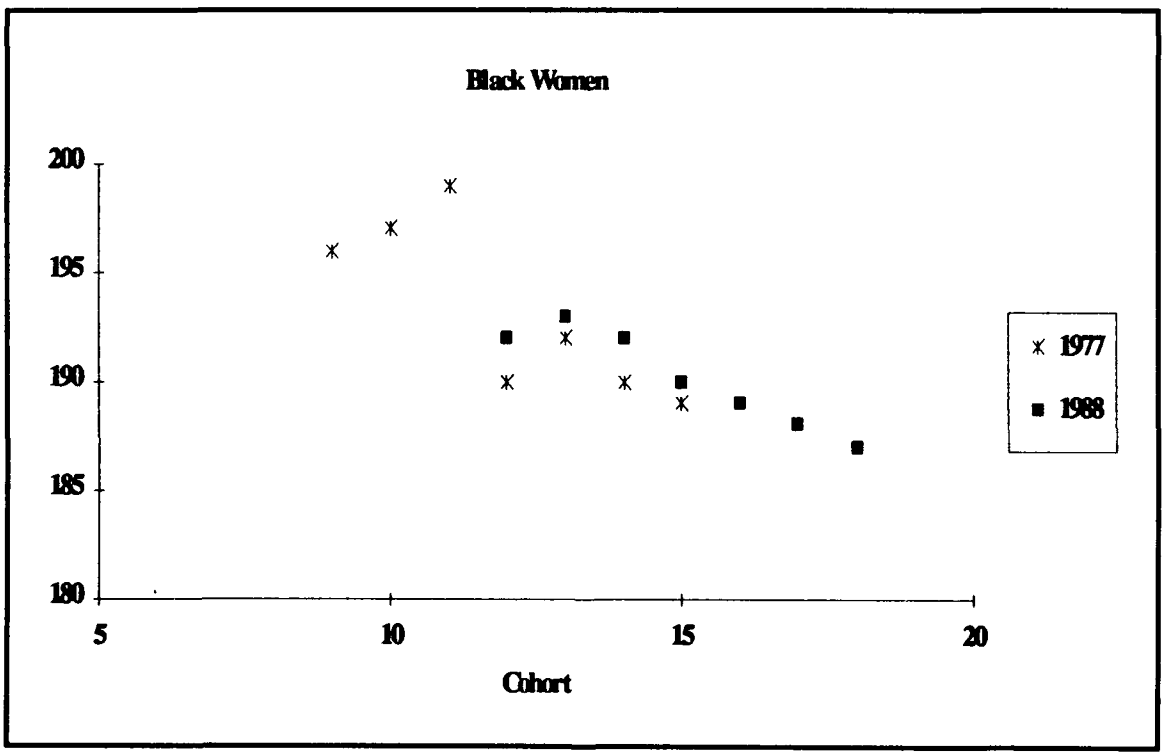
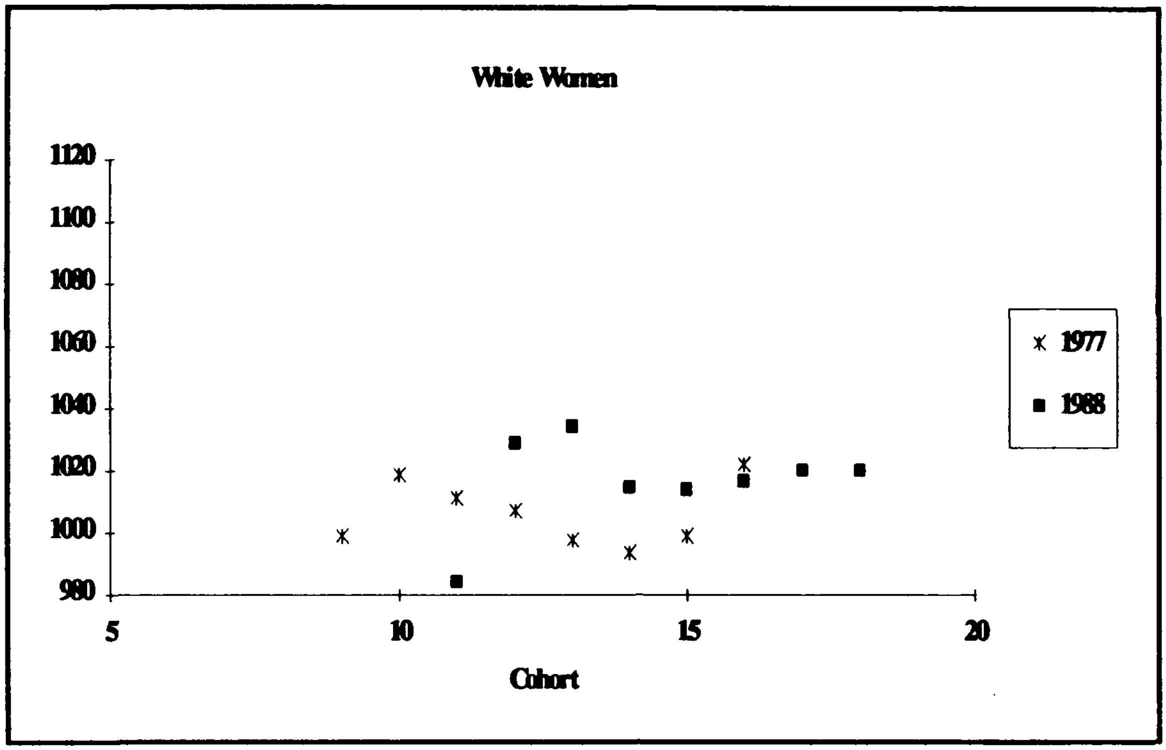


Figure C-10. Head Length (mm) vs. Birthyear Cohort



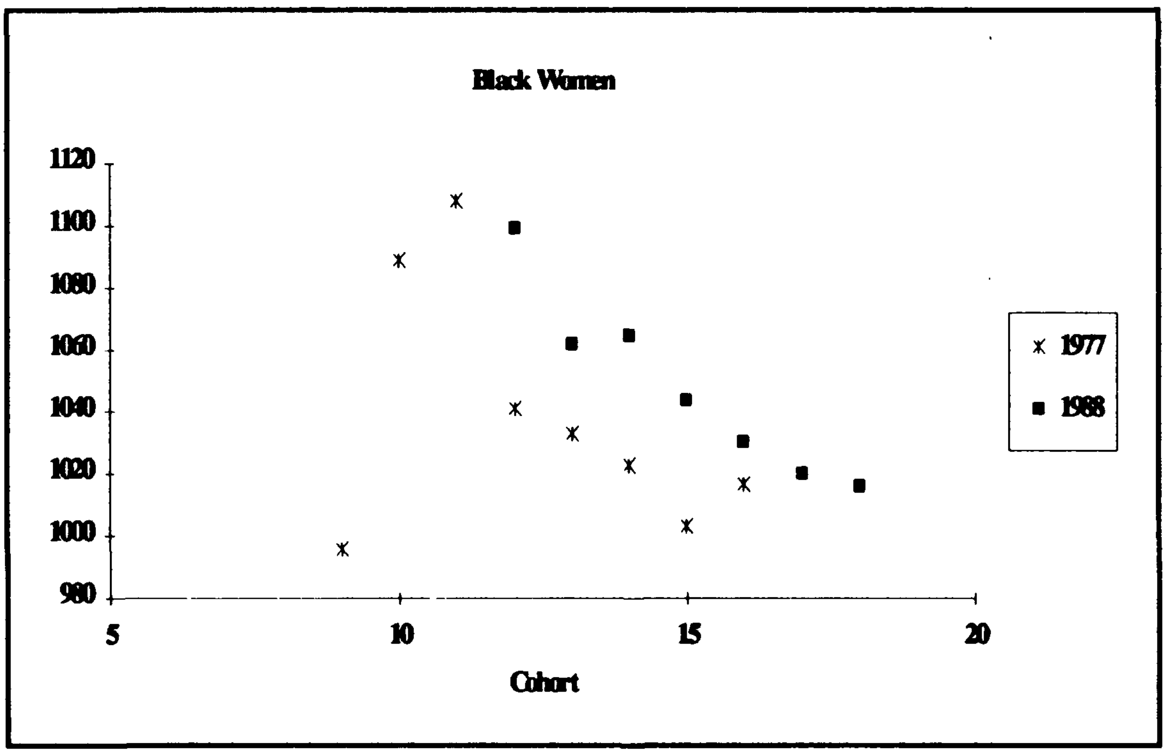
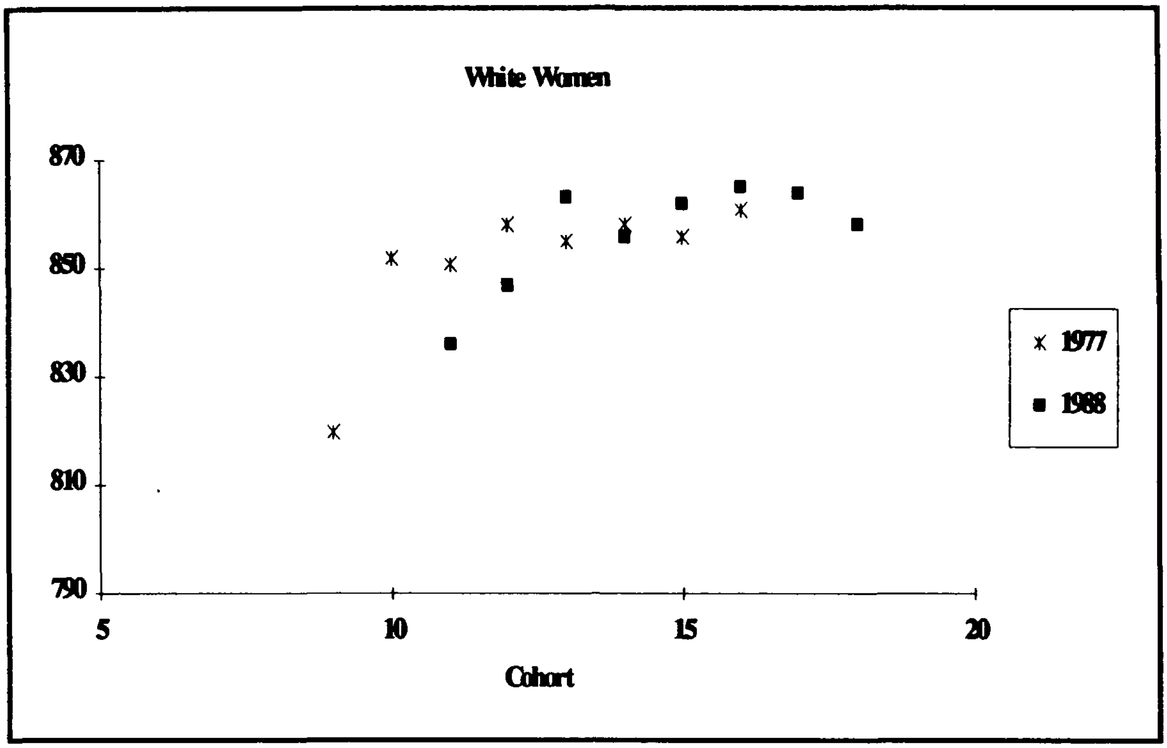


Figure C-11. Shoulder Circumference (mm) vs. Birthyear Cohort



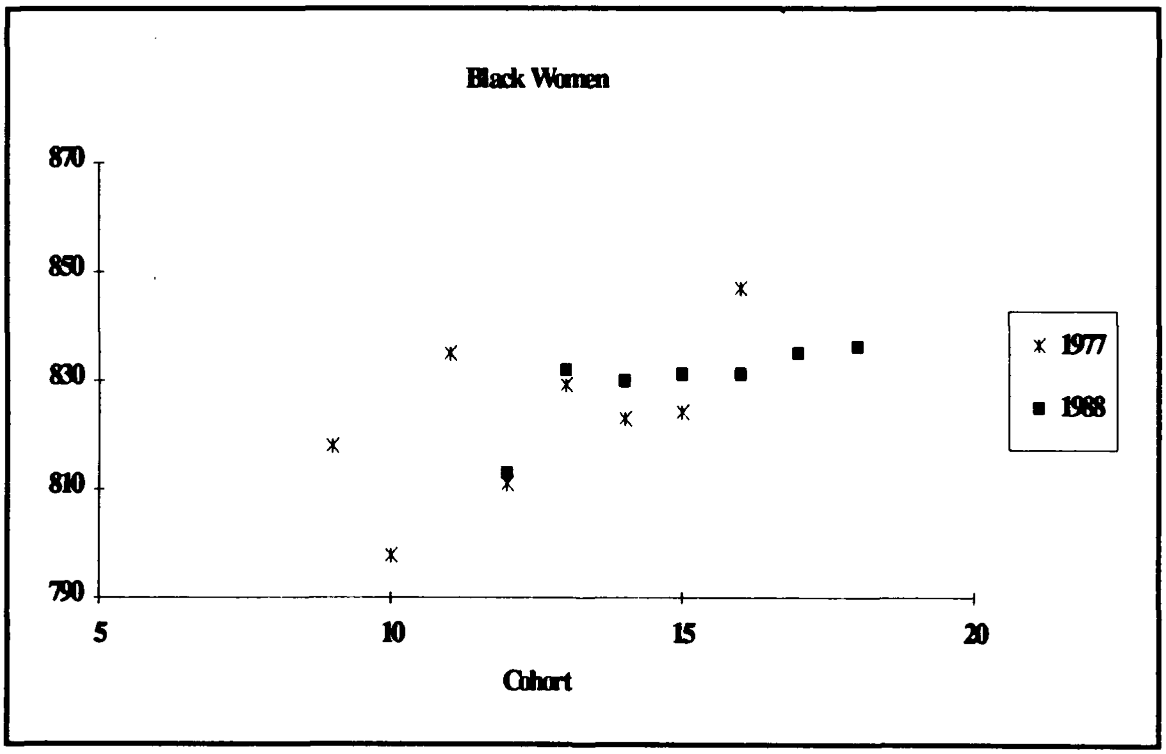
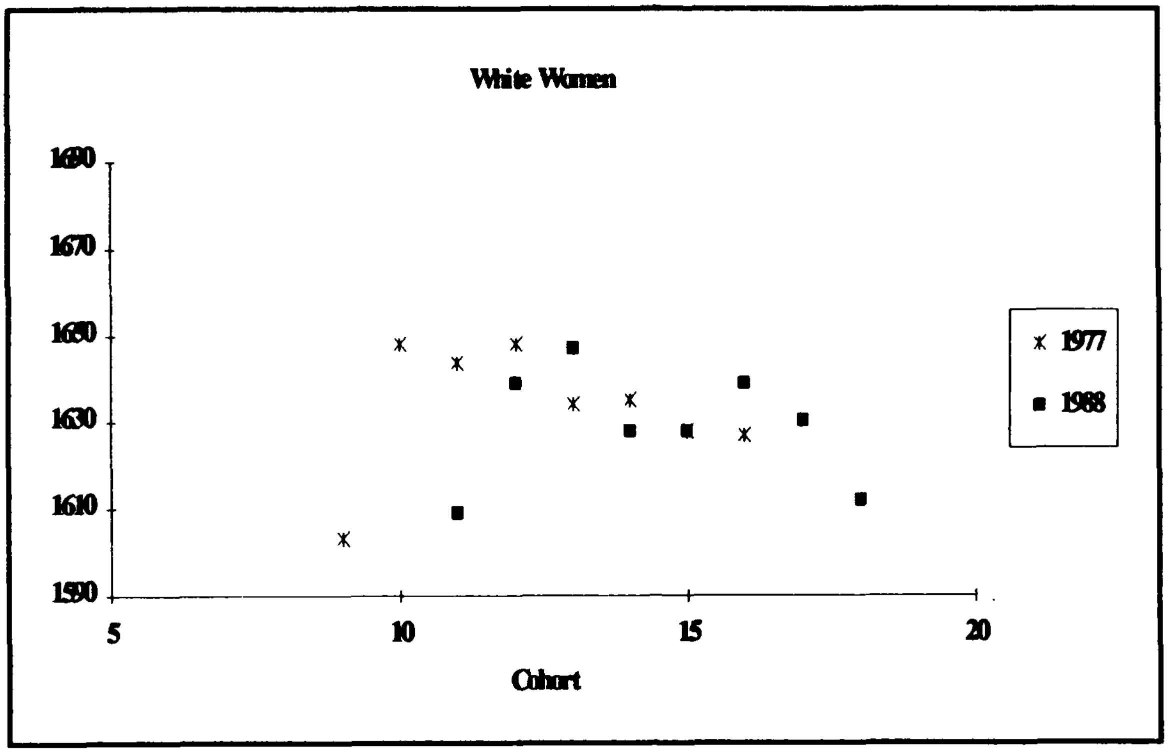


Figure C-12. Sitting Height (mm) vs. Birthyear Cohort



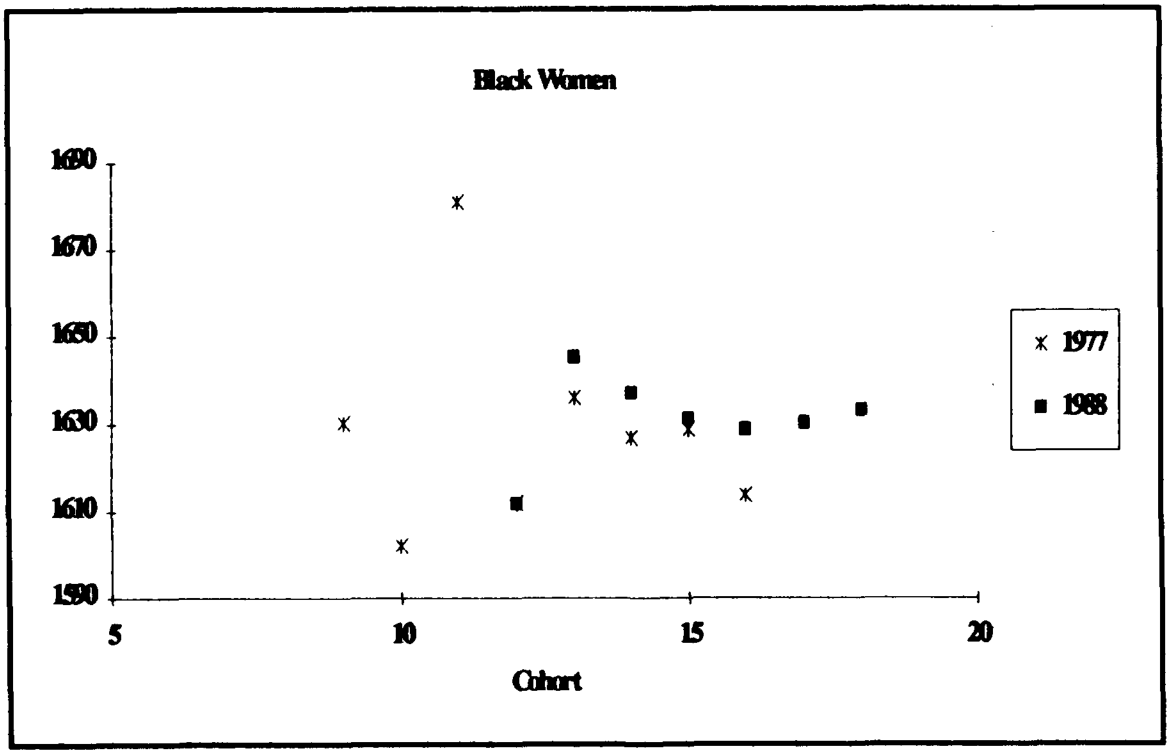
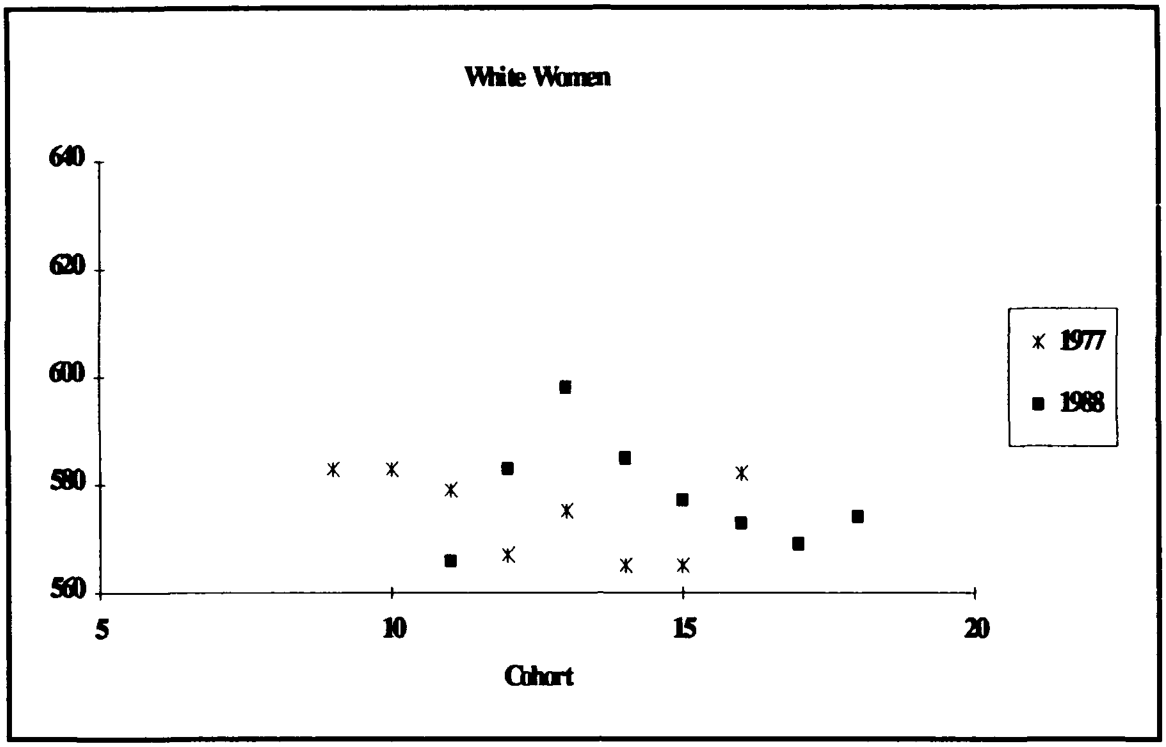


Figure C-13. Stature (mm) vs. Birthyear Cohort



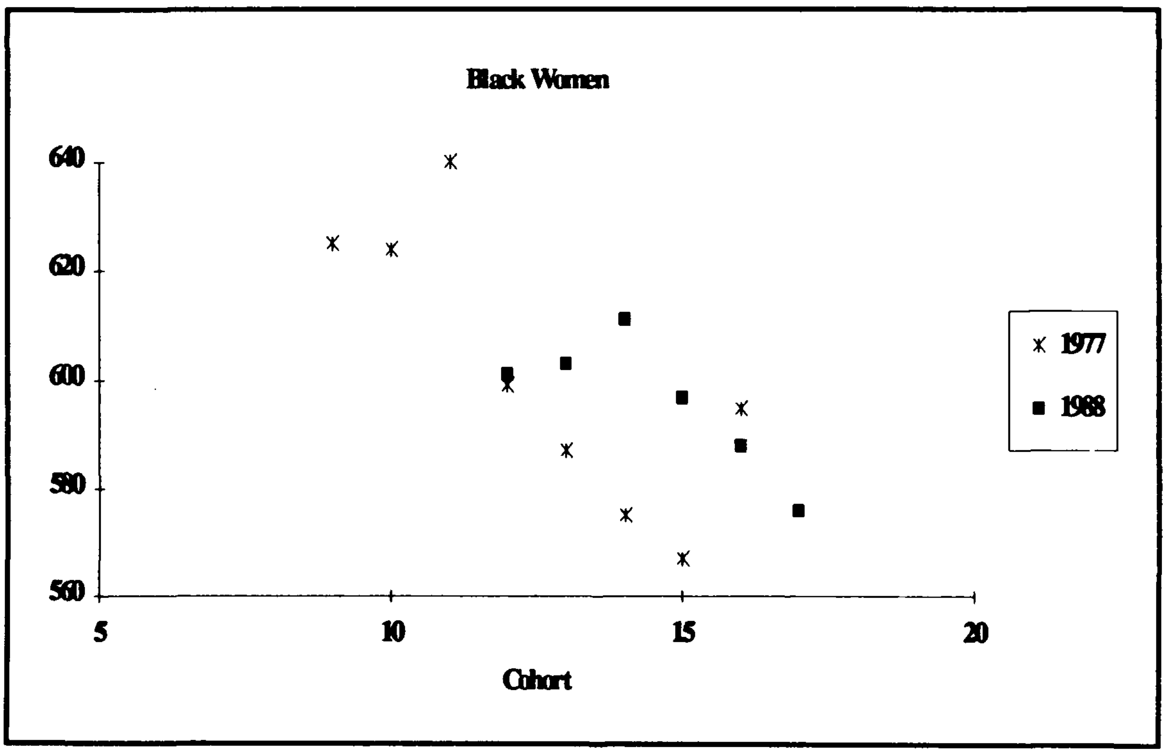
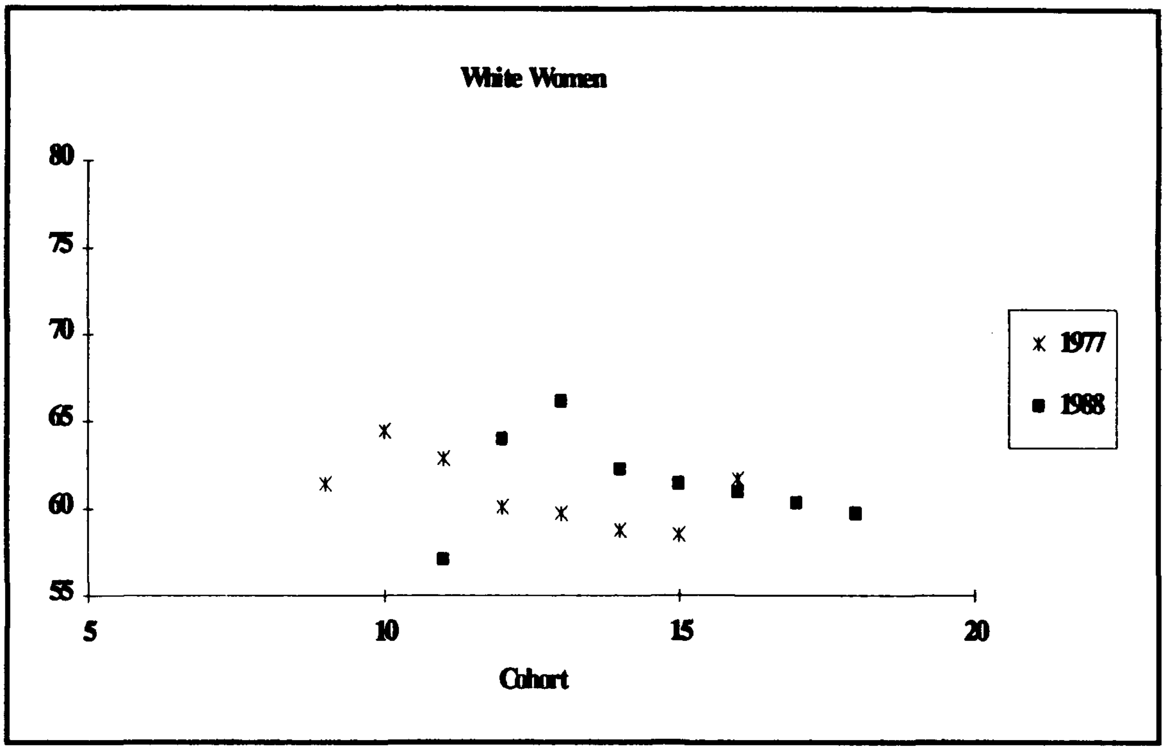


Figure C-14. Thigh Circumference (mm) vs. Birthyear Cohort



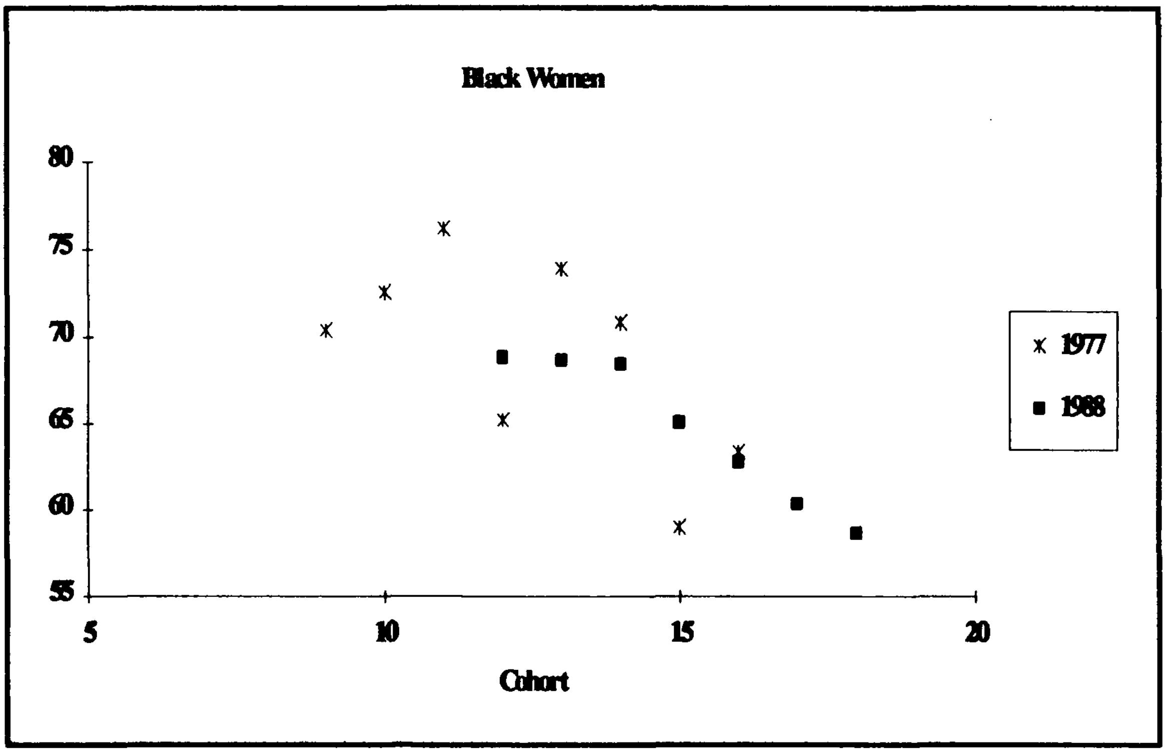


Figure C-15. Weight (kg) vs. Birthyear Cohort